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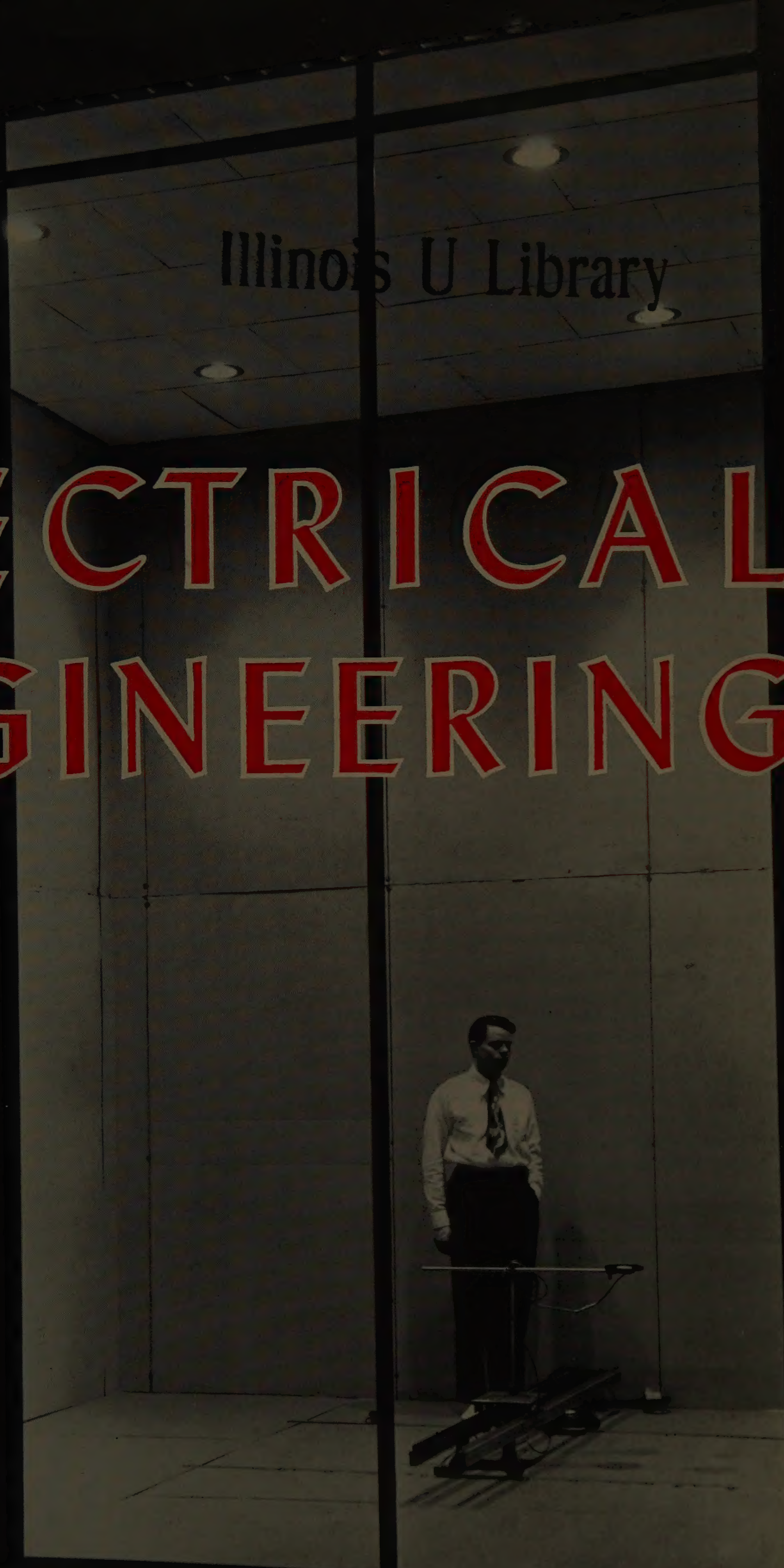

JULY
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The Cover: The lighting measurements laboratory at General Electric's Nela Park is shown. Adjustable walls and ceiling make it possible to obtain information about the lighting requirements of areas of many sizes and proportions. (See story on page 650 in the *Current Interest* section.) General Electric Company photograph

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HIGHLIGHTS........

The Power to Progress. President LeClair reviews a half-century of progress in the electric power industry, and states that in coming years the engineering profession has even broader opportunities ahead (*pages 563–5*).

Submerged Repeater for Ocean Cable. A description of an underwater repeater installed in a transoceanic telegraph cable is presented in this article. The repeater, at a depth of 270 fathoms, more than tripled the operating speed of the cable (*pages 566–70*).

Magnetrons for Dielectric Heating. A magnetron capable of 5-kw output at 915 megacycles has been developed specifically for dielectric heating applications. This tube and apparatus for heating dinners and plastics are discussed (*pages 627–33*).

Microwave Equipment for Industrial Communication. An analysis is made of a particular 940–960-megacycle communication set. Among the subjects treated are frequency choice, frequency control, methods of modulation, antennas, and receiver problems (*pages 573–8*).

Renaissance in Electrical Education. The author compares the curriculum of 1925 with that of 1950 and discusses the changes that the field of electronics has brought electrical education (*pages 581–4*).

Giovanni Giorgi. This brief article presents some of the highlights of the career of Giovanni Giorgi (1875–1950), who possessed the qualities of both theoretician and practical engineer (*pages 587–8*).

News Index

Experiments with Peltier Effect. The Peltier effect, which causes an absorption of heat when a current flows across the junction of two unlike metals, has been investigated lately. The introduction of new alloys increases the possibility of putting the effect to practical use (*pages 589–91*).

Winding Insulation Tester for D-C Armatures. Apparatus for testing d-c armature insulation by the use of surge voltages has been developed. To provide test potentials of 500 volts' peak on the low bar-to-bar resistance of the commutator, small ignitrons were incorporated in the design (*pages 591–4*).

Oil-Well Pumping Motors. A study of properties desired in motors for pumping oil wells shows that dripproof or protected-frame motors will be satisfactory for most locations. Motors with slip from 5 to 8 per cent are generally best for the type of load which oil-well pumping imposes (*pages 598–601*).

Tube Surveillance in Large-Scale Computers. With 18,000 vacuum tubes involved in one computer, the problem of their maintenance is a major one. Tubes were checked, and their histories recorded; the results of a survey show that some 5,000 tubes had to be replaced over a 5-month period (*pages 605–7*).

Electricity as Primary Energy for Space Heating. Human comfort, considered from a thermal viewpoint, depends on the mean radiant temperature of the enclosing surfaces, ambient air temperature, direction and intensity of air movements, and the relative humidity. Tests show that electric panel heating provides these factors in a way that competes with conventional heating methods (*pages 608–11*).

Formed Power Transformer Cores. When cold-rolled oriented strip steel was introduced into transformers, new types of distribution transformer cores were developed. These cores were of the wound type and utilized the magnetic properties of oriented steel very efficiently. Recently, a new type of single-phase power transformer core using oriented steel has been developed and put into production (*pages 614–17*).

Measurement of Metal Wall Thickness. Finding the thickness of metal pipes, boilers, and so forth, is an important industrial problem. This can be done by setting up ultrasonic resonance waves in the metal—their frequency is a measure of thickness—so that the measurement can be done from one side. A portable instrument for doing this is described (*pages 619–23*).

AIEE Proceedings

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All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

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Jul '50, p 30A	Winter General; North Eastern District; Great Lakes District; Summer and Pacific General
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Mar '51, p 35A	Winter General
Jul '51, p 23A	Southern District; North Eastern District; Great Lakes District; Summer General

Sensitive Relays in Process Control. Engineers faced with control problems will find in this article some useful information on sensitive instrument type relays. Nonmagnetic and magnetic types are discussed and some typical circuits are presented (*pages 625–6*).

Electrical Essays. A. A. Kroneberg tells about an odd network in this month's essay, and the answer to "A 4-Point Network" is given (pages 623–4).

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

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The Power to Progress

T. G. LeCLAIR
PRESIDENT AIEE

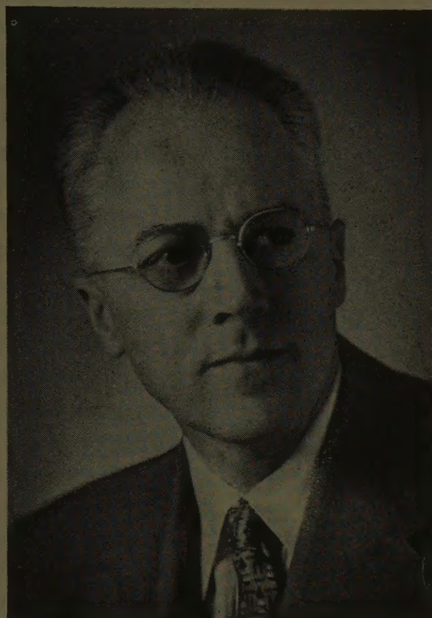
To industry, electric power is the power to progress. It is the power to produce more goods and services with a given number of men. The Institute also has the power to progress by advancing electrical engineering as the key to the electrical industry.

NOW THAT WE have passed the half-century mark, it seems appropriate to cover ıat has taken place and what we ıy expect in one phase of this ctrical industry, rather than to ver the entire field of electrical gineering for a year. The elec- c power industry is the only e on which I feel competent to eak, and this half-century of ogress may furnish some inter- ing thoughts for engineers in all anches of the profession. All of are interested in the utilization electricity in connection with r daily work, even more, perhaps, ın we may realize.

At the turn of the century, the stitute was only 16 years old, d electrical engineering, as we ow it, was also in the knee- eeches stage of development. en today, after 50 years of further progress, while we have oadened tremendously, the profession is still in the ung and growing stages and subject to some of the cessary growing pains.

Not much progress in the production of goods and services s made by mankind in the thousands of years up to the ne of the industrial revolution. On the other hand, y rapid progress has been made toward better living ring the lifetime of our older members, and this progress the lifetime of the Institute has been much greater than all of man's previous history. Man's early tools, such the wheel and screw and lever, were helpful, but with wer for these implements furnished by the physical ertion of men and animals, production per man-hour was cessarily limited. With the advent and the rapid owth in the use of electric power, which is convenient, ghly adaptable, and economical, the production per an-hour has been increased tremendously; furthermore, developments of many new machines, materials, and vices have been stimulated or made possible.

Even when man made use of animals or a water wheel, steam or combustion engines, to increase his productivity, still the power source and the use of the power were bound together at one location. The source of power might be much too small or much too large for the task at hand. Also, the power production was often inefficient and costly. In any event, the source required much space in relation to the production facilities, and usually lacked flexibility.



T. G. LeClair

On the other hand, electric power is unique in both production and use. With the advent of electricity, it has become feasible to select locations best suited from the standpoint of over-all efficiency to convert the primary power into electricity on a bulk-power basis. The electric power can be transmitted and distributed to the users and their equipment exactly at the location where needed, in the form suitable for the particular utilization purposes, and in amounts only as required. Then we have the final conversion, that is, electricity into power to drive a machine, or into light, or into sound in the radio or telephone system, or into heat, and so forth.

The relation of electric power to the economic progress of the United States is shown by the fact that although it has only 7 per cent of the world's population, it produces nearly half of the world's electricity. Last year, production was about 388,000,000,000 kilowatt-hours, while the next greatest production, in Russia, which has a larger population, was less than one-fourth as much. With about 5 per cent of the world's area and 7 per cent of the world's people, the United States produces over 80 per cent of those things that make for good living as against mere existence.

The commercial use of electricity had been in effect for almost 20 years at the turn of the century, but during the past 50 years the total annual production of electricity in the United States has increased about a hundredfold.

Figure 1 shows the over-all increase in the use of electric energy in the United States on a per capita basis from 1920 to date. These data are based on the sum of the

ntially full text of an address presented at the AIEE Summer General Meeting, onto, Ontario, Canada, June 25–29, 1951.

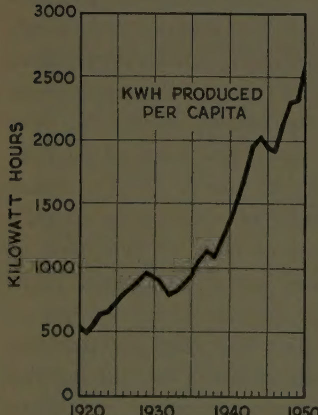
. LeClair is chief electrical engineer, Commonwealth Edison Company, Chicago, Ill.

production by utilities contributing to the public supply and by those industrial establishments which operate generators, with 85 per cent coming from the former in 1950. In 1920, when some of us were finishing our electrical engineering courses, the annual production of electricity was about 500 kilowatt-hours per capita. Now, only 30 years later, the production of electricity has grown to over 2,500 kilowatt-hours per capita. This spectacular growth in three decades brings to my mind a picture of the ever-increasing and ever-widening uses of electric power in the factory, mine, office, public place, farm, and home.

Since 1882, when Edison and his friends started the operation of the first utility to supply electricity to the general public, the power that assists each American factory worker has increased from $1^1/_3$ horsepower to almost 8 horsepower. Prior to that period, none of the power was electric; now, almost all of it is electric.

To my mind, a better indicator of the importance of electric power in industry is the actual kilowatt-hour usage per year for each production worker in manufacturing plants. Figure 2 shows how this rate has grown in the past 30 years. In that rather short period, the usage per worker has quadrupled. Last year the average production worker in manufacturing industries used about 13,000 kilowatt-hours of electric energy. This amount of energy is equivalent to the physical efforts of about 100 men working 40-hour weeks for one year. This figure of 100 is, of course, an approximation, as methods of calculation give results varying from 75 to 200 men.

Observations in factories bring out no end of illustrations of the flexibility of electric power in enabling the individual worker to perform tasks in a convenient and efficient manner. In each case there are interesting instances of how electric power, combined with machinery, requires only a fraction of the manpower that was previously required. This is seen in machines and associated apparatus used in canning factories, in making lamp bulbs, in steel mills, and so forth. The electric-light bulb is made by a large machine which costs many thousands of dollars but which requires the attention of only a few girls. The result is a bulb that now costs less than a tenth of what it did in the beginning of the century, even though the costs of materials and manpower have increased considerably. In this case, as in many others, the product also is improved.



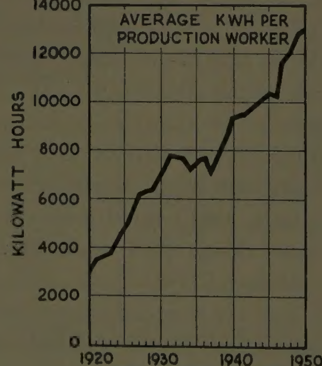


Figure 1 (left). Production of electricity in the United States

Figure 2 (right). Use of electric power in United States manufacturing industries

In other fields, such as at new power stations having centralized control, the use of electric signals and speech communication has reduced the manpower requirements. Centralized control systems, which utilize electronic as well as 60-cycle circuits, reduce the operating personnel needed in the boiler room, turbine room, operating gallery, and around the electric apparatus. As a result of using these improvements in the new Ridgeland Station near Chicago, the required operating force is only about one-half of what would be necessary for the same units operated as in the older stations.

While the horsepower per factory worker has risen to six times its initial value in the electrical age, the standard work week has decreased from 60 to 40 hours. Furthermore, the physical exertion required in doing factory work has been decreased greatly by the use of power-driven machines. The gain of 20 hours per week available for recreational, cultural, and other pursuits represents more of a gain than may be apparent at first. The better working conditions and less physical exertion resulting from the use of electric light and power leave the worker in much better mental and physical condition to enjoy his increased leisure time.

During the same period, that is, since the beginning of the electrical age, the purchasing power of the factory worker has practically tripled. This sharp increase is a direct result of many things including, in particular, the harnessing of electric power to increase the production per man-hour.

Although 75 per cent of the electricity used in factories operates motors, much is used for lighting and, more recently, for such operations as infrared heating, dielectric heating, and electric furnaces. New or improved products or improved operations have resulted frequently. For example, the use of electric furnaces has made possible some new and higher quality steels, from which we have produced gas turbines, jet engines, and other new or more efficient machines.

The increased use of electricity in factories has been accelerated by its relatively minor cost. In the past few years, the cost of electricity used in factories has been, on the average, three-fourths of one per cent of the selling price of the factory products.

Another field in which electric power has contributed greatly to better living has been in our homes. Thirty years ago electricity was used there mostly for lighting. Now, electric power is used in over two-thirds of our homes for refrigeration, washing, ironing, and for clocks and radios. Many other electric appliances are in common use, such as vacuum cleaners and electric ranges. It is somewhat surprising to see how rapidly the newer electric devices are being adopted for home use; for example, over 10,000,000 have television sets, 2,800,000 have food freezers, and 2,300,000 have electric blankets. Lighting now constitutes only about one-third of the usage of electricity in the home, even though we have been adopting

ger and more numerous light sources for useful and orative lighting. The over-all result has been the enomenal growth depicted in Figure 3.

This again presents data on the unit basis, that is, in owatt-hour consumption per year for each residence ng electricity. Last year this usage was 1,830 kilowatt-urs per residence, or $5^1/_2$ times the unit usage in 1920. s interesting to note that even during years of business essions and depressions, the average residential con-ner always has increased his usage over the previous r.

Here again the increase in the use of electricity for a iety of purposes has received impetus from the relatively cost of the electricity. The average expenditure for usehold electricity is only nine-tenths of one per cent of total personal expenditures. The average family has n spending nearly as much money for movies as for ne electricity, and spends $2^1/_2$ times as much for smoking.

The use of electric power on farms has grown very idly in recent years. Whereas in 1925 about 250,000 ms, representing only 4 per cent of the total, had electric vice, by 1930 the utilities had increased this ratio to 10 cent. Now, over 90 per cent are using electric service, d it is available to over 95 per cent of the farms. The rage usage on the farm has grown rapidly, as in the ne, mainly because the farmer is using electricity for ny operations formerly performed by his own physical orts or with the assistance of animals. In 1950, the total owatt-hours used on farms was about 5 per cent of the al use in the country, but it was five times greater than farm use only 10 years earlier.

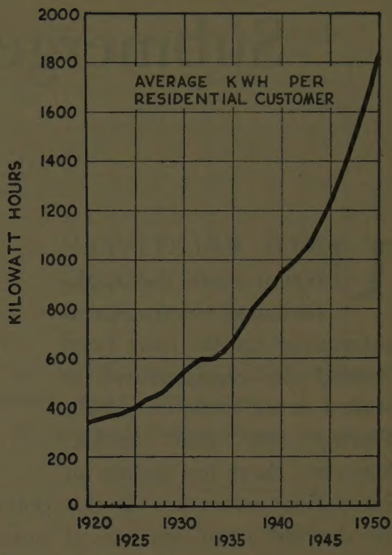
Of course, this outstanding growth in the use of electric ver in the factory, in the home, and on the farm, and attendant progress, is the combined result of a number factors and of the contributions of various groups of ople. One group, the electrical engineers, has played eading part in this picture. Not only have we designed d operated larger generators, motors, transformers, oles, and the like, and developed new types of equipment producing and distributing the greater amounts of ergy required, but these things have been made with reased economy of materials and labor. In addition, portant improvements in efficiency of operation and in ability of service have been effected.

Almost every new product which is invented and put o production requires some new machine for its pro-ction. The list of these new machines is almost endless, d almost every one is powered by electricity, the source power which can be used the most efficiently and can applied at any point where it is desired. From auto-biles to hearing aids, and from arc furnaces to television, ctrical engineering and electric power are the essence of modern standard of living and of the economic strength our country. We depend upon electric power almost much as on the air that we breathe.

WHAT OF THE FUTURE?

VERY ONE OF US has an ambition to work shorter hours, d to have an easier job, and to have more of the com-ts of living—more time for recreation, cultural, and

Figure 3. Use of electricity in the home



civic affairs. This is as it should be. This is the foundation of modern progress. To me this can mean only one thing. If we are to have more production in fewer hours, we must use more electric power and must produce more electric power to do the work of production. Last year the production of electricity in the United States was almost 400,000,000,000 kilowatt-hours, which is a number so large that I, for one, have not the power to visualize it. The peak demand for electric power from the utilities was about 64,000,000 kw last year, and the latest forecast is that this demand will increase one-third in about three years.

The title of this address, "The Power to Progress," was chosen as a two-edged sword. To industry, electric power is the power to progress; it is the power to obtain more production for a given number of men employed. It is the essential for human progress. Also, the Institute has the power to progress by further advancing electrical engineering and by acting as spokesman for a growing industry. In the last 67 years, we have progressed through war and peace, through depression and boom, with a continually growing number of members and a continually expanding field. We are in a profession with even broader opportunities ahead than those which we have had up to the present time. We must not only go forward but we must attract more men to the profession if we are going to do our duty in carrying forward the modern standard of living. Engineers have the power to progress, and electrical engineers look to the Institute to furnish the leadership which is so necessary in a broad and co-operative industry.

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Submerged Repeater for Ocean Cable

C. H. CRAMER
MEMBER AIEE

An underwater repeater recently installed in one of the early transatlantic telegraph cables more than tripled the operating speed of the cable. This development, coming at the centenary of the submarine cable, is expected to have wide application.

UNTIL RELATIVELY recent years, the applications of electronics to submarine cables have been limited to equipments installed at the cable terminals. During the past decade, however, there has grown an increasing awareness of the potentially great benefits to be derived from the use of intermediate submerged repeaters. The initial proposals[1] and practical applications[2,3] of such devices have been in the field of wide-band circuits involving the use of new coaxial-type cables and repeater spacings of 50 miles or less. This article describes an experimental installation of a submerged repeater in a long transoceanic cable, the first application of such a repeater to an existing low-speed d-c telegraph cable.

The repeater was installed during September 1950 by the cable ship *Cyrus Field* on one of The Western Union Telegraph Company's North Atlantic cables, *1PZ*, extending from Bay Roberts, Newfoundland, to Penzance, England. This cable, 2,148 nautical miles in length, has been operated in recent years with a signal-shaping vacuum-tube amplifier at the receiving terminal, the cable station at Bay Roberts. Prior to the installation of the repeater, the westward simplex or 1-way printer operating speed of the cable, limited by the interference level, was 50 words per minute. With a single repeater inserted in the cable at a point 170 miles northeast of Bay Roberts, just beyond the Newfoundland Banks and 270 fathoms deep, the operating speed is 167 words per minute.

PRINCIPLES OF THE SUBMERGED REPEATER

THE FOLLOWING discussion of the submerged repeater will be related specifically to *1PZ* cable for the sake of directness, but the principles involved are general.

1PZ, one of the slowest-speed cables of the Western Union system, was laid in 1881. The original cable was of types *350/300* and *450/270* (weight of copper per weight of insulation in pounds per nautical mile). Currently, original cable in the circuit is 428 nautical miles or about 17 per cent. During repairs and renewals, type *650/375* cable has been used extensively and is now the major type, about 39 per cent of the total length. The average age of the cable is 25 years. The attenuation of the cable, without repeater, is given in curve *A* of Figure 1. At a frequency of 6.25 cycles per second, corresponding to a speed of 50 words per minute, the attenuation is 71 decibels; while the attenuation at 20.83 cycles, corresponding to a speed of 167 words per minute, is 117 decibels.

The profile of the ocean bed east from Newfoundland along the route of *1PZ* is shown in Figure 2. The cable profile is of particular significance with respect to the disturbance level on the cable. Electrical disturbances originating in the atmosphere and induced on the surface of the ocean are attenuated in propagation downward through the seawater.[4] The attenuation increases with frequency as indicated by Figure 3, which gives the magnitude of attenuation per fathom for sinusoidal disturbances through the range of cable telegraph frequencies. Thus, at a depth of 250 fathoms, 20-cycle disturbance has undergone attenuation of about 80 decibels. Knowing the cable profile and assuming uniform distribution of potential on the surface of the ocean, the relative amplitude of the disturbance induced in various sections of the cable conductor can be evaluated. Summation of the sectional disturbances, taking into account the attenuation and phase characteristics of the cable, gives a relative amplitude of total disturbance level at the cable terminal. For *1PZ* with Bay Roberts as the receiving terminal, the curve of Figure 4 shows the portion of 20-cycle disturbance originating in the section of the cable beyond any point *X* miles from Bay Roberts. For example, if *X* is 150 miles, then of the 20-cycle disturbance level at Bay Roberts only 0.1 per cent originates in the 2,000 miles of cable east of *X*. For distances greater than 150 miles, the residual disturbance decreases rapidly as indicated by the curve. An amplifier can be introduced in the cable 160 or more miles from Bay Roberts without appreciably increasing the terminal disturbance level.

THE REPEATER

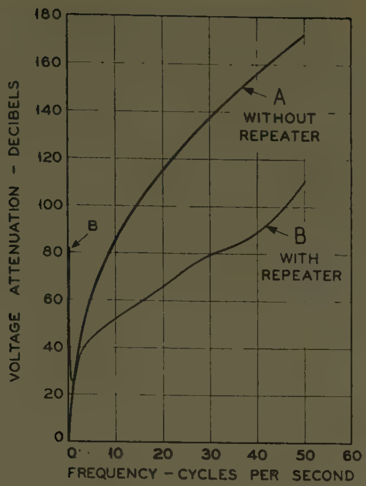
ELECTRICALLY, the repeater, shown schematically in Figure 5, comprises a 3-stage push-pull resistance capacitance coupled amplifier with input and output transformers. A simple tuned signal-shaping network precedes the input transformer. Type *5693* tubes are used in all stages, with two tubes in parallel and operated as triodes in each side of the output stage. The required signal output is determined principally by the low-frequency components of the signals.

The power requirements of the repeater, 0.32 ampere at 125 volts, are supplied from Bay Roberts over the single cable conductor which also serves as the signal transmission medium. The impedance of the power supply

Essential text of paper **51-286**, "Submerged Repeaters for Long Submarine Telegraph Cables," recommended by the AIEE Committee on Wire Communications Systems and approved by the AIEE Technical Program Committee. Originally presented as a conference paper at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951, and presented as a technical paper at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

C. H. Cramer is with the Western Union Telegraph Company, New York, N. Y.

Figure 1. Attenuation of 1PZ cable



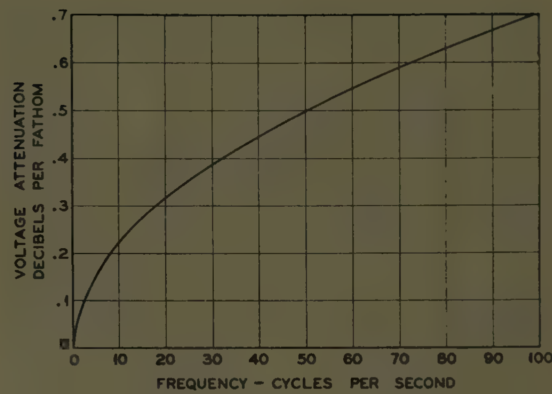


Figure 3. Attenuation of sinusoidal disturbance in seawater

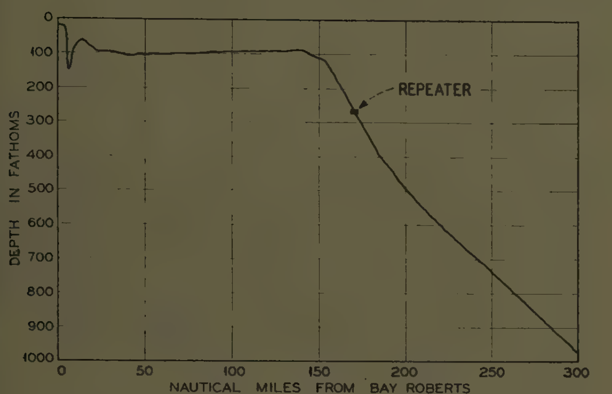


Figure 2. Profile of the 1PZ cable from Bay Roberts

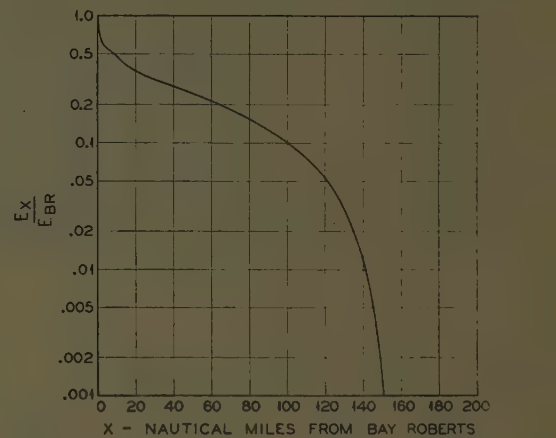
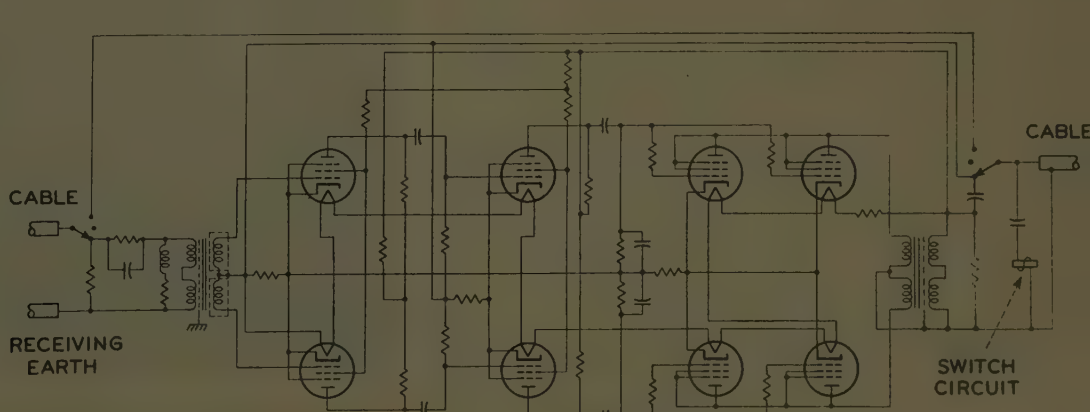


Figure 4. Ratio of 20-cycle disturbance, originating X miles from Bay Roberts to total 20-cycle disturbance at Bay Roberts

relatively high, including resistance of 550 ohms at the terminal and 170 miles of cable having resistance of about 295 ohms. This condition tends toward repeater instability which is heightened by the narrow range available for discrimination between power supply and the low-frequency signal components. Measures taken at the repeater to provide stable performance include a high-capacitance by-pass, careful selection and matching of vacuum tubes, and utilization of negative feedback.

The frequency-response characteristic of the repeater, Figure 6, increases with frequency to a maximum at about 42 cycles per second where the gain is 67 decibels. With the repeater in circuit, the over-all frequency-attenuation characteristic of *1PZ* is as shown in curve *B* of Figure 1. No change of disturbance level is observed at Bay Roberts when the repeater is switched into the circuit. It is of interest to note that without a repeater, the received level of 20.83-cycle signals would be 27 decibels below the disturbance level. On the other hand, to obtain a satisfactory receiving level at 20.83 cycles without repeater, a sending level of +85 decibels (316 kw) would be required. It is important that the required output level at the repeater be low because of the limitations imposed by available vacuum tubes and by the power supply. To satisfy this requirement, the repeater should be located as near to the receiving terminal as consistent with natural and crossfire disturbance conditions. Aside from considerations of signal power level at the repeater, the power-supply

Figure 5. Circuit of the repeater. Type 5693 tubes are used in all stages



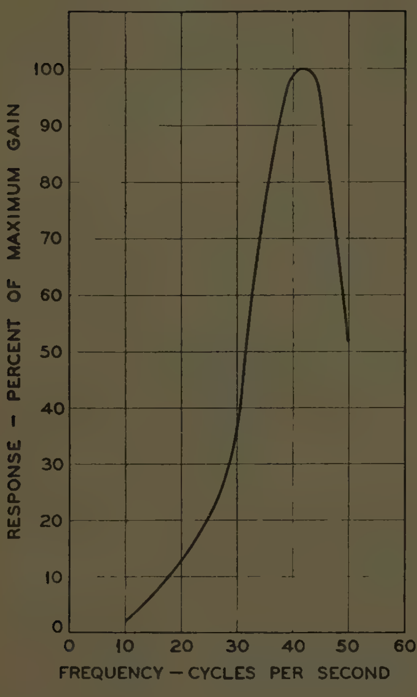


Figure 6. Frequency response curve of the repeater

voltage imposed on the cable at the terminal increases as the repeater is moved away from the terminal by reason of the greater voltage drop in the cable.

The repeater includes a rotary ratchet-stepped switch which has two principal functions: (1) to disconnect the repeater and join the cable through for operation without repeater or for cable testing purposes; (2) to "swap" vacuum tubes in the event of a tube failure. Three complete sets of tubes are provided and can be utilized in 18 different combinations. The switch is operated as required from Bay Roberts by trains of 60-cycle sine-waves. The operating winding of the switch, in series with a capacitor, is connected from cable to ground at the repeater.

MECHANICAL DESIGN OF THE REPEATER

Since it was planned to install the repeater in a depth of between 200 and 300 fathoms, the major requirement to be met in the mechanical design was suitability for extended operation under hydrostatic pressures up to 750 pounds per square inch. Components for low-frequency communication equipments are inherently bulky. It thus appeared inadvisable to attempt to design a housing of the size required in which the interior would be at or near atmospheric pressure. Instead the repeater is filled with oil and a pressure equalizing bellows automatically adjusts the internal pressure to the external pressure within a few pounds per square inch. The equalizer has sufficient capacity to take up any small voids resulting from incomplete filling of the housing and to compensate for the relatively large volumetric temperature coefficient of the oil. At sea bottom, particularly in areas and depths involving arctic currents, the temperature may be as low as 30 degrees Fahrenheit. To minimize the change of volume and thus the capacity of the equalizer, metal filler is utilized to reduce the amount of oil required.

Since the external-internal pressure differential is small, a gasket of synthetic rubber provides an adequate seal.

The repeater components are mounted on a rectangular chassis, Figure 7, occupying a space approximately 10 inches by 11 inches by 26 inches. Certain of the components are subjected directly to the full hydrostatic pressure. These are: (1) the capacitors which, with the exception of small by-pass capacitors, are all of the oil-filled paper-foil type; (2) the inductor and the transformers, which are of the wound-core type, having windings impregnated with Acme Compound; and (3) most of the resistors, which are wire-wound and spiral metal-film types.

The vacuum tubes are in standard metal-shell bulbs which are not of sufficient strength to withstand the hydrostatic pressure encountered. The tubes, together with certain related resistors, are mounted in steel cylinders, six tubes to a cylinder. Figure 8 shows a tube cylinder and a completed tube chassis, ready for insertion. In completing the assembly, steel plugs are pressed into the ends of the cylinder, and fins on the plugs are soldered to corresponding fins on the cylinder. Connections are brought out through high-pressure terminals in the end plugs. Four tube cylinders are provided, one each for the first and second stages, and two for the output stage.

The rotary switch, Figure 9, also is enclosed in a cylinder identical in design with the tube containers, except that it is somewhat longer. The switch operating mechanism is balanced so that it will function in any position.

The repeater chassis is fastened to the cover plate. The two cable leads and the receiving-earth lead are brought out through glands mounted in the cover plate.

As shown in Figure 10, a cable entrance chamber is mounted on the top of the cover plate. Holes (not shown in this photograph) are provided in the end channels for the entrance of fully armored cable stubs, one in each channel. A concentric circle of small holes permits the individual armor wires to be looped back through the channel and firmly secured to the cable. The cores of the stubs are spliced to the gland cores within the entrance chamber. Side plates and a top plate complete the enclosure of the chamber, allowing entrance of seawater but protecting the unarmored cores within from mechanical damage. A heavy lowering eye on the top plate provides

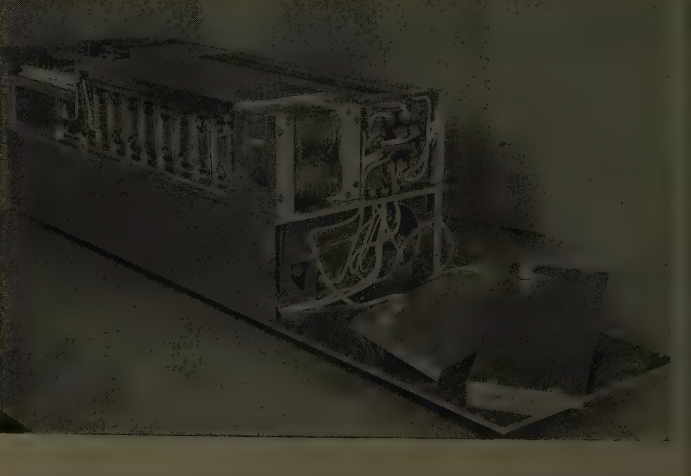


Figure 7. The repeater chassis with components in place

a means of eliminating hazardous strains on the cable at the points of attachment to the repeater. For each of the two cable stubs, a chain extends out from the eye followed by a stranded steel rope which is spliced to the cable armor about 15 feet from the repeater in a manner to allow some slack in the cable between that point and the repeater.

The repeater case proper is 12 inches wide by 11 inches deep and the corresponding dimensions of the cable entrance chamber are somewhat larger. The over-all length is about 51 inches. The complete repeater weighs 1,140 pounds.

INSTALLATION OF THE REPEATER

At best, the operations involved in splicing a structure of the size and weight of the repeater in a submarine cable and placing it safely on the bed of the ocean depart considerably from the normal operations of cable ships. Unfavorable weather conditions introduce further complications. In one method, perhaps the least difficult, the ship would pick up the cable as in normal repair operation, heaving to at the planned repeater location with both ends of the cable on board. After completion of the splices, the repeater would be lowered. This procedure is not desirable, however, because the resulting slack cable might loop on the bottom so as to cause feedback effects in the repeater. Such effects are avoided in the method actually used. The cable was picked up at a point more than a mile east of the repeater location and the end of the eastward section was buoyed. The ship then proceeded to the repeater location, picking up the intervening cable. At that point, the cable was cut and the required splices were made. Then the repeater was lowered over the bow sheaves, the ship got under way and, paying out cable as in a normal repair operation, proceeded to the buoy where the final splice was made. In this method, once the repeater is free of the ship its weight is supported by the cable, except in the short sections on either side of the repeater where the load is transferred to the steel cable and chain arrangement described previously.

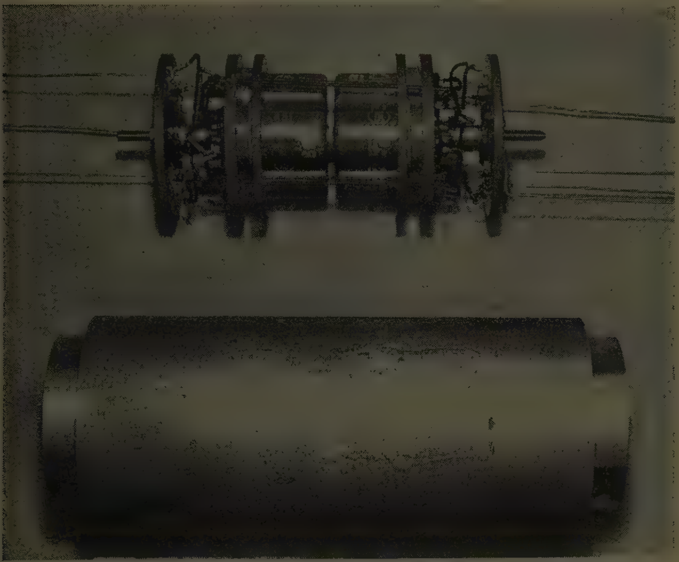


Figure 8. Completed tube chassis and a tube cylinder

Figure 9. Repeater switch assembly and its cylinder

Figure 10. View of repeater showing cable entrance chamber

It is desirable that the position of the final splice be sufficiently distant from the repeater to insure that the repeater is resting on the bottom and is not in suspension during the final splicing operation. That the measures described were fully effective is confirmed by the fact that after the repeater was first lowered to the bottom, it was successfully picked up and brought on board ship. The installation was carried out under rather unfavorable weather conditions and the final result is indeed a tribute to the staff and crew of the cable ship, where skill and efficiency of a high order are traditional.

THE TERMINAL EQUIPMENT

The receiving terminal circuit at Bay Roberts is shown schematically in Figure 11. The arrangement is

similar in general to a standard duplex cable terminal, except that the bridge arms are resistors instead of capacitors. Power for the repeater is supplied by rectifiers and fed into the apex of the bridge, while a standard signal-shaping amplifier is connected across the diagonal of the bridge and functions in the usual manner. The bridge is balanced by an artificial line which simulates the section of cable between the terminal and the repeater and the impedance of the repeater to ground so that the terminal amplifier is unaffected by noise components in the power circuit. Since the current required at the repeater is 0.32 ampere, the drop in the bridge arm and cable totals approximately 275 volts and an electromotive force of about 400 volts normally is applied between apex and ground to produce 125 volts at the repeater. Automatic controls maintain the power current at a constant level despite power voltage fluctuations and in the presence of a wide range of earth potentials. When earth potentials exceed the range of the controls or if for any other reason the power current approaches a predetermined safe limit, a circuit breaker functions to protect the repeater. The rack-mounted installation of rectifiers and control equipment is shown in Figure 12.

CONCLUSION

THUS FAR only one repeater has been constructed. It was installed without having been tested previously under hydrostatic pressure because pressure-testing equipment was not immediately available and because early operating trials were desired. During the service tests, the predicted speed of 1,000 letters (167 words) per minute was obtained without difficulty and excellent performance has been obtained in traffic operation as part of a London-New York varioplex circuit. The soundness of the principles upon which the development was based has been fully confirmed, justifying plans for further development and application of the repeater.

As might be expected, certain improvements of both the repeater and the terminal control equipment have been suggested by the experience with this initial installation. The most important, perhaps, is that future repeaters should be suitable for installation in greater depths. Present indications are that, on the input side of the repeater, it is desirable to avoid near-by crossings with other cables because of crossfire conditions. On congested cable routes most of the crossings occur in the two coastal areas. In general, repeaters should be located beyond the crossings at the receiving end of the cable. The crossings near the distant, sending end are unimportant from the standpoint of crossfire, since the signal level in that section of the cable is very high. On many cables, as compared with the installation on *1PZ*, such a requirement can be fulfilled only by installation in deeper water and at greater distances from the receiving terminal.

Figure 12. The power supply and control equipment

The cables suited to application of repeaters are of various lengths and types so that there is a relatively wide divergence in transmission characteristics among individual cables. For this reason, repeater design cannot be standardized in all respects. For example, the optimum signaling speed of an individual cable depends upon the cable characteristics and the terminal disturbance level, and the design of the repeater network must be carefully predetermined for the chosen speed since there is no opportunity for readjustments once the repeater is installed.

There is no experience upon which to base predictions of repeater life. It can be expected confidently that longer life will be realized as designs are refined and improved components become available. In any case, aside from the cost of manufacturing a repeater, the cost of an installation is little more than the cost of a routine cable repair operation. It appears, therefore, that while an ultimate life of 5 to 10 years or more is desirable and can probably be achieved, the increase in signaling speed is large enough to support renewals at intervals of two years or less.

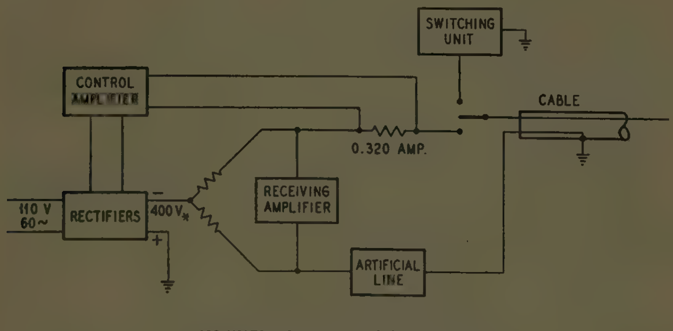


Figure 11. Receiving terminal and repeater power supply circuit

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Graphical Synthesis of Networks for A-C Servos

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'HE PERFORMANCE of a servomechanism is often improved by modifying the data signal with compensa- networks. For a-c servomechanisms, a-c (sometimes ned carrier-frequency) compensation networks are bloyed which modify only the modulation, because the a appear as modulation on a carrier. To determine effect on the data signal of such an a-c compensation work, let us examine the action of the 2-phase motor demodulator.

'he demodulated output of the 2-phase motor, the que, is proportional to the modulation of the com- ient of control-winding voltage in quadrature with the itation winding voltage. This component of control- ding voltage is in phase with the modulator reference, e the excitation-winding voltage is adjusted to be in drature with the modulator reference, and hence is ned the direct component. The transfer function ting the modulation of the direct component to the a signal is designated as $G_d(j\omega_m)$; while the transfer ction relating the modulation of the component in drature with the modulator reference to the data signal lesignated as $G_q(j\omega_m)$. Except for secondary factors, lected in this discussion, $G_d(j\omega_m)$ represents the effect on the data signal of the a-c compensation network, le $G_q(j\omega_m)$ shows the amount of unwanted quadrature nponent.

et us synthesize an a-c compensation network, with nsfer function designated as $D(j\omega)$, which will produce same effect upon the data signal as a given d-c (or a-frequency) compensation network, with transfer ction designated as $G'(j\omega_m)$. (Note that ω_m is the data, modulation, frequency; ω the frequency of the a-c e being transmitted through the a-c network, and the carrier frequency.) To produce zero quadrature nponent, the function $D(j\omega)$ should be symmetric about carrier frequency ω_0, as shown by the dotted $D(j\omega)$ ves, and the transfer function of the modulation of direct component $G_d(j\omega_m)$ that it produces should be al to $G'(j\omega_m)$. This cannot be achieved exactly, yet y be approximated closely by replacing each $(j\omega_m)$ in $j\omega_m)$ by the expression $(1/2j\omega)$ $[(j\omega)^2+\omega_0^2]$ in order orm the transfer function $D(j\omega)$ which is shown by the d curves.

'o determine the exact effect of the a-c compensation work $D(j\omega)$ thus formed, evaluate G_d and G_q as follows. d the plots of $D(j\omega)$ about the ω_0 axis, with the lower e-band phase curve inverted, and shift them to the a distance ω_0, forming $G^+(j\omega_m)$ the upper side band, $G^{*-}(j\omega_m)$ the conjugate of the lower side band, as shown. Alternatively, G^+ and G^{*-} need not be computed, but can be obtained directly as shown by shifting points on G' positively and negatively, respectively, the frequency interval: $\Delta\omega_A=\sqrt{\omega_0^2+\omega_A^2}-\omega_0$, where ω_A is a specific data frequency. (This shift is facilitated by the use of templates.) G_d and G_q then can be obtained from the relations

$$G_d=(1/2)(G^{*-}+G^+);\quad G_q=(1/2j)(G^{*-}-G^+)$$

Carrier drift, often a basic limitation in the use of a-c compensation networks, may be analyzed as follows. For a negative drift of the carrier to the frequency $(\omega_0-\Delta\omega_0)$, shift the plot of G^{*-} negatively and that of G^+ positively by the frequency interval of drift, $\Delta\omega_0$. Reverse, for a positive drift.

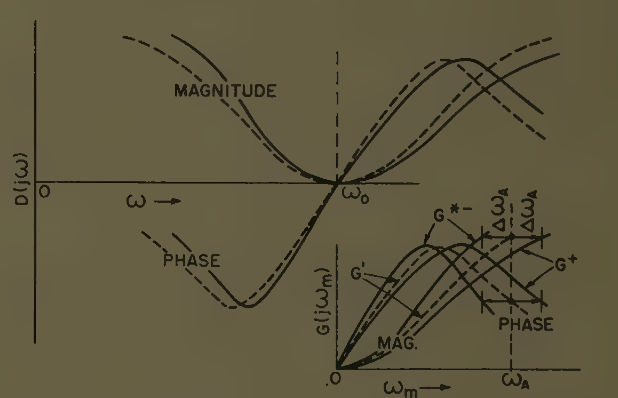

Figure 1. Determination of $G^{*-}(j\omega_m)$ and $G^+(j_m)$ from the a-c function $D(j\omega)$

If the effect of $D(j\omega)$ is not adequate, other a-c networks may be developed by employing the more general substitution: $j\omega_m\rightarrow(1/2j\omega)$ $[(j\omega)^2+(r\omega_0^2)]$, using if desired different values for (r) for each factor of G'. A factor of D thus formed will be balanced about the frequency $(r\omega_0)$ rather than (ω_0). To plot the corresponding G^{*-} and G^+ functions, assume the carrier shifts temporarily to the frequency $(r\omega_0)$, and employ the templates, indexing them at this new carrier frequency. Then allow the carrier to shift back to its normal value (ω_0), accounting for this by shifting G^{*-} negatively and G^+ positively the same frequency interval: $\Delta\omega_0=(r\omega_0-\omega_0)$. With this more general substitution, a factor $(i\omega_m+\omega_1)$ of G' becomes $(1/2j\omega)$ $[(j\omega)^2+2\omega_1(j\omega)+(r\omega_0)^2]$. Thus, a perfectly general quadratic factor is formed. Hence, the side-band plots of any a-c compensation function D composed of quadratic factors can be obtained simply by reversing this substitution. Each factor of D becomes a single-order factor of G', which is shifted by the appropriate amounts to obtain G^+ and G^{*-}.

t of paper **51-101**, "Network Synthesis by Graphical Methods for A-C Servo- anisms," recommended by the AIEE Committee on Feedback Control Systems approved by the AIEE Technical Program Committee for presentation at the E Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled ublication in AIEE *Transactions*, volume 70, 1951.

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Absorption Studies on High-Voltage Machines

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IN CONJUNCTION with basic studies of a-c and d-c test methods to evaluate the conditions of machine insulations, a number of dielectric absorption tests were made on new high-voltage stator windings using d-c test voltages ranging from 5,000 to 40,000 volts. A total of 78 machines rating from 15,000 to 135,000 kva were tested. Because the application of high-potential d-c test voltages is necessarily limited to machines whose insulation is capable of withstanding such voltages without damaging effects, the voltage class of all of the machines tested was in the range of 11.0 to 14.4 kv. The insulation was essentially the same for the entire group of machines consisting of multiple layers of continuously applied mica tape.

The data obtained are grouped according to test voltage and then analyzed statistically. Frequency distribution curves are plotted before and after corrections for machine size and atmospheric moisture are applied. It is shown that corrections for moisture and machine size increase the central tendency of the data, indicating that the corrections are valid and of the proper magnitude.

Dielectric absorption data show that the absorption time is generally shorter at the higher test voltages than at the standard 500- or 1,000-volt test although no appreciable difference in absorption time is noticeable between the 5-, 10-, 15-, and 20-kv tests. There is also definite indication that the insulation resistance for essentially dry windings is generally greater at the higher test voltages than the 500-volt insulation resistance. For normal and slightly moist windings the insulation resistance is generally lower

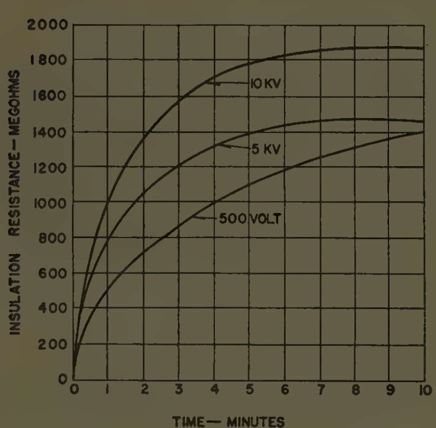

Figure 1. Dielectric absorption curves of 31,250-kva turbine generator. Polarization index at 500 volts equals 2.94

at the higher voltages than the 500-volt insulation resistance. Typical dielectric absorption curves showing the effect of moisture on insulation resistance are shown in Figures 1 and 2.

Figure 1 represents an essentially dry winding while Figure 2 may be considered normal for a new winding exposed to atmospheric conditions in the shop.

Corrections for machine size are made on a unit volum basis. Thus, all insulation resistance values are expresse in megohm inches as determined from the effective are and thickness design data of the insulation neglecting th end windings.

Corrections for temperature and humidity are referre

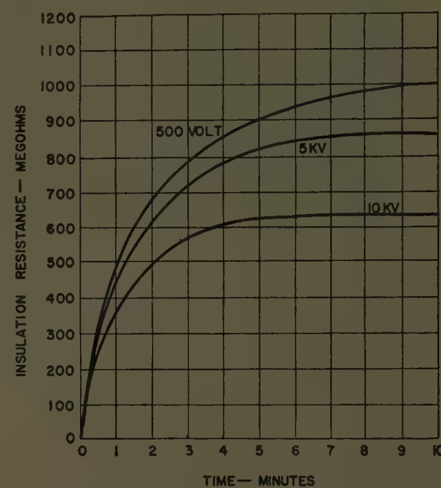

Figure 2. Dielectr absorption curves 35,294-kva turbin generator. Polariz tion index at 50 volts equals 2.08

to standard conditions of 70 degrees Fahrenheit an 50-per cent relative humidity. This reference point wa chosen to reduce the possibility of error, because mo of the data were obtained at or near this temperatur No attempt was made previously to apply correctio factors for atmospheric humidity on insulation resistan of a-c windings. In attempting to apply a correction fo the effect of atmospheric moisture on insulation resistanc the total moisture content of the air at the time of te should be taken into consideration. The corrected insula tion resistance is the measured resistance multiplied b the ratio of the vapor pressure at test conditions to the vap pressure at standard conditions. The validity of th correction factor is demonstrated by the reduction in th standard deviation with an increase in central tendency the frequency distribution data.

It is apparent that the primary advantage of hig voltage d-c insulation resistance tests is that the measur ments are obtained under electrical stress conditions whi are equivalent to the stresses encountered during machi operation. It may be possible under these stress conditio to detect the location of insulation weaknesses and lo resistance creepage paths which could not be detected wi a 500- or 1,000-volt megger.

Digest of paper 51-129, "Dielectric Absorption Studies at Higher Voltages on La Rotating Machines," recommended by the AIEE Committee on Rotating Machin and approved by the AIEE Technical Program Committee for presentation at AIEE Winter General Meeting, January 22–26, 1951. Not scheduled for publicat in AIEE *Transactions*.

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940–960-Megacycle Communications Equipment for Industrial Applications

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Microwave equipment uses the same kinds of parts applied in the same general manner as in low-frequency equipment. However, because of the wide frequency spectrum available, realizable antenna gains, propagation characteristics, and economic considerations, microwave equipment is widely different from low-frequency equipment in design and application.

ISCUSSIONS on the reasons for development, the technical details, the application of micro-e communications equip-nt have been presented viously.[1–3] A study of the ematics for these equip-nts makes it obvious that rowave equipment is made of arrangements of parts which differ widely from those mally encountered in electronic equipment for indus-l applications. The purpose of this article is to show this difference exists. For example, a microwave re-er may need 20 or more tubes and a power-line carrier eiver may require only one tube.

FREQUENCY

HE MOST OBVIOUS difference is in the frequency at which the equipment operates. Generally speaking, fre-ncies of about 1,000 megacycles and higher are con-ered microwave frequencies. Certain bands of fre-ncies have been set aside by the Federal Communica-s Commission for fixed station operation for industrial lications. These bands are shown in Table I.

he choice of frequency band is dependent on many fac-. Among these are availability of components, propa-on characteristics, number of signals to be transmitted, type of modulation. The design of the equipment de-ds to a large degree on the band chosen.

he Westinghouse type *FB* equipment will operate in the –960-megacycle industrial band. Some of the reasons this band was chosen are:

. There is adequate spectrum for the services contem-ed.

. The use of many conventional circuits is permitted, ng lower initial cost and cheaper maintenance costs.

. Availability of suitable components at low cost.

. Better propagation characteristics.

. Simpler installations since equipment may be located oors in convenient positions and connections made to nna with low-cost conductors.

FREQUENCY CONTROL

IS DESIRABLE for spectrum economy and mandatory ecause of governmental regulations that the center or ier frequency of most radio communications systems be constant within very narrow limits. These limits ally are specified as a percentage of center frequency are met in low-frequency equipment by using crystals or inductance-capacitance circuits whose electrical constants do not vary appreciably with temperature, voltage, or loading.

As frequency goes higher with crystal oscillators, the point is reached where crystals cannot operate at transmitter output frequencies and multiplier stages must be added after the crystal oscillator to get the desired output frequency. The multiplier stages have the disadvantage that they multiply the error in center frequency and also give undesired frequencies which may interfere with other services.

As frequency goes higher with ordinary inductance-capacitance circuits, the circuit elements get so small that the changes due to thermal expansion alone are often sufficient to cause excessive drift in carrier frequencies. It is necessary to make these elements of materials having high dimensional stability or to go to elaborate circuits to compensate for the variations.

Table I. Frequencies for Fixed Industrial Stations

Band, Megacycles	Bandwidth	
	Megacycles	Per Cent
952– 960	8	0.84
1,850– 1,990	140	7.3
2,110– 2,200	90	4.1
2,450– 2,700	250	9.7
6,575– 6,875	300	4.5
12,200–12,700	500	4.0
16,000–18,000	2,000	11.8
26,000–30,000	4,000	14.3

When the carrier frequency of a communications transmitter and the local oscillator of a communications receiver vary, there are two ill effects. First, fewer channels can be placed in a given bandwidth, and second, the acceptance band of the receiver must be greater, permitting additional noise to be received. To illustrate this point at several frequencies, Table II was prepared assuming amplitude modulation with maximum modulating frequency of 3 kc, transmitter and receiver local oscillators each with a frequency stability of 0.005 per cent, and noise of constant amplitude at all frequencies.

Table II demonstrates that even with relatively good frequency control the amount of spectrum used up due to

Full text of paper 51-144, "940–960-Megacycle Communications Equipment for Industrial Applications," recommended by the AIEE Committee on Carrier Current and approved by the AIEE Technical Program Committee for presentation at the AIEE Southern District Meeting, Miami Beach, Fla., April 11–13, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Table II. Frequency Spectrum With One Signal

Frequency, Megacycles	Transmission Bandwidth Required, Kilocycles	Receiver Bandwidth Required, Kilocycles	Relative Receiver Noise Voltage
0.1	6.005	6.01	1
1.0	6.05	6.10	1.08
30	7.50	9.00	1.22
150	13.5	21.0	1.87
1,000	56.0	106.0	4.20
2,000	106.0	206.0	5.88
6,000	306.0	606.0	10.1

variations in transmitter center frequency gets very large with respect to that required for intelligence transmission and further that the wide receiver bandwidths, necessary to make allowance for these variations, permit excessive noise to be accepted. The poor use of the spectrum illustrated in Table II for single-channel amplitude modulation is one of the reasons why single-channel microwave equipments are seldom used. If several communications circuits are multiplexed and this composite signal used to modulate one microwave carrier, much better use is made of the spectrum. This can be demonstrated by the example of Table III based on multiplexing four signals (on an amplitude-modulation basis with 2-kc guard bands) and using the same oscillator stability as in Table II.

Table III. Frequency Spectrum When Using Four Signals Multiplexed

Frequency, Megacycles	Transmission Bandwidth for Four Signals, Kilocycles	Receiver Bandwidth for Four Signals, Kilocycles	Receiver Bandwidth Per Signal, Kilocycles
0.1	27.005	27.01	6.752
1.0	27.05	27.10	6.775
30	28.5	30.00	7.50
150	34.5	42.00	10.50
1,000	77.5	127.00	31.75
2,000	127.0	227.00	56.75
6,000	327.0	627.00	156.75

An analysis of the receiver bandwidth per signal given in the last column of Table III leads to the conclusion that very close frequency control is desirable if the microwave spectrum is to be used efficiently. It is obvious from Table I, however, that at the higher frequency bands there is enough spectrum available to allow for bandwidths per si nal which would be prohibitive at lower frequencies.

In the design of the type *FB* microwave equipment, cry tal control was supplied for both transmitter center-fr quency control and receiver local-oscillator control. Th receiver crystal operates at about 28 megacycles and followed by multiplier stages particularly designed to min mize the production of spurious signals. The transmitte crystal operates at about six megacycles. This low fr quency was necessary because of the type of modulatio To minimize spurious signals, all multiplier stages in th transmitter up to 160 megacycles were made push-pu triplers which have practically no even-order harmonic At the higher frequencies, the multiplier stages we shielded to reduce spurious output.

The variations in transmitter output and receiver loca oscillator frequencies for a 50-degree variation in ambie temperature are each ±15 kc, giving a total increase in r ceiver bandwidth to make allowance for frequency var ation of approximately ±30 kilocycles or 0.003 per ce of center frequency.

METHOD OF MODULATION

As has been shown, the use of amplitude modulatio with realizable frequency stabilities results in poo usage of the spectrum and results in reduced signal-to-nois ratios. Frequency modulation, pulse-time modulatio pulse-code modulation, and other systems which give bett signal-to-noise ratios at the expense of a not too gre percentage increase in bandwidth required per chann normally are used in microwave equipments. The gener type of modulation used in a frequency band is determine by available components, techniques, and bandwidth well as economic considerations.

In present-day microwave systems, phase and frequenc modulation are usually used when the number of sign channels to be transmitted over a single microwave equi ment is less than ten. This is true whether the signal is a kc-wide voice-frequency circuit or a 4-megacycle-wi television circuit. When the number of channels greater than ten, pulse-type systems usually are used.

In selecting the type of modulation to be used on the ty *FB* equipment, it was decided that a maximum of seve voice-frequency channels would me most of the industrial applications f which it was intended. Crystal co trol was desirable for the reaso outlined previously. An analysis methods for obtaining suitable mod lation with crystal control led to t conclusion that phase modulating low-frequency crystal output a multiplying its deviation to obta the desired deviation in the tra mitter output would be the simpl and most foolproof system.

Phase modulation has the chara teristic, however, that the amou of deviation is directly proportion to the frequency of the modulati

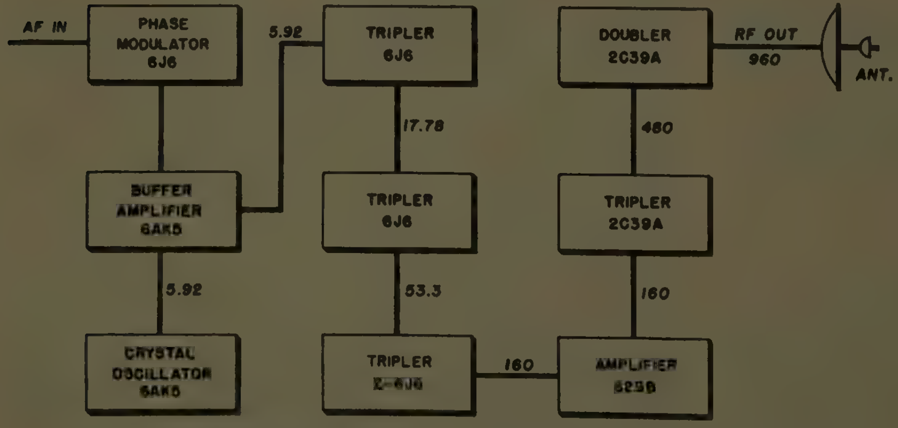
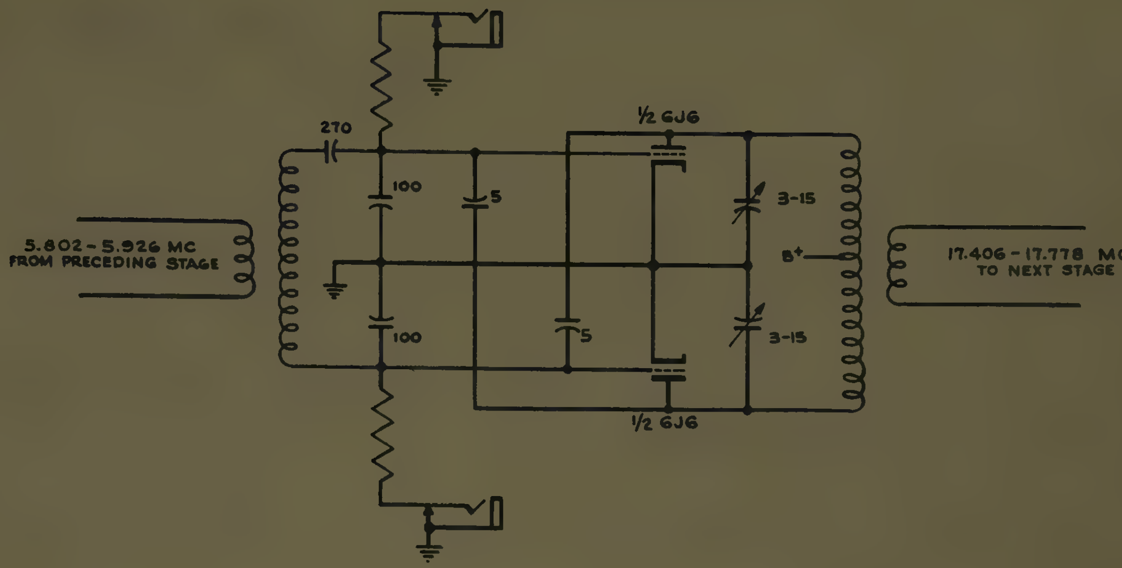


Figure 1. Block diagram of complete ultrahigh-frequency transmitting system

ure 2. Schematic
gram of push-pull
ler stage used in
rowave transmitter



nal. At first, it would appear that this is desirable ce it gives a constant deviation ratio and improve- nt in signal-to-noise ratio for all modulating fre- encies. An analysis of the characteristics of the noise countered in an operating system, however, indicates it low-frequency noise predominates and that the same nal-to-noise ratios can be obtained at high modulating quencies with a greatly decreased deviation ratio. Accordingly, it was decided to modulate the transmitter h a signal whose amplitude was inversely proportional to quency to give essentially constant deviation at all odulating frequencies. Thus, the equivalent of fre- ency modulation has been obtained indirectly without excessive cost of center-frequency stabilization required direct frequency modulation and at the same time a jor saving in bandwidth over phase modulation has en made.

To minimize crosstalk and intermodulation in the sev- l signals to be transmitted, it is necessary that the dis- tion introduced by modulation be very low. Usually, riable reactance circuits are used in phase modulators, d very accurate tuning of the reactance circuit is required obtain very low distortion with most such circuits. The ase modulator used in the type *FB* equipment is a vari- le conductance type which is not highly critical in adjust- nt for distortion percentages less than one per cent. is phase modulator uses a triode tube and shifts the phase the current in a plate tank circuit which is common to the odulator and a buffer amplifier which is driven by crystal oscillator. The complete ultrahigh-frequency nsmitter is shown in block diagram in Figure 1 with tube types indicated.

FREQUENCY MULTIPLICATION

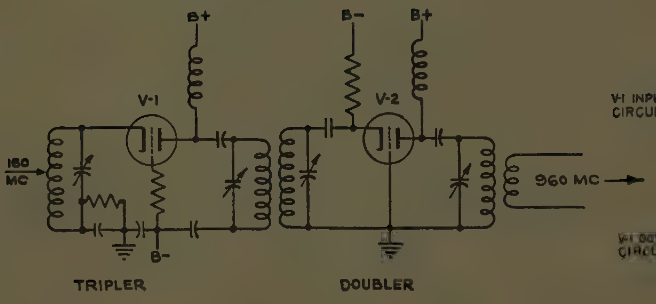
S INDICATED, it is not possible to get oscillator crystals which will operate at frequencies in the microwave ectrum. If crystal control is used in a microwave trans- tter, it is necessary to multiply the output of the crystal illator to get the desired output frequency. Also, if tortion is to be kept at a minimum in a phase modulator, range of phase deviation in the modulator must be kept small, necessitating several subsequent multiplier stages if a reasonable deviation ratio is to be obtained in the output signal.

In the type *FB* equipment, the transmitter crystal frequency of approximately six megacycles is determined by the low-distortion requirements and the required deviation ratio. Tests proved that (1) within the allowable distortion limits a frequency deviation of about 200 cycles was the maximum permissible, and that (2) an output deviation of approximately 35 kc was required for the desired signal-to-noise ratio. These two factors determine that a multiplication of about 160 times is required in the transmitter.

Multiplication increases the possibility of spurious radiation and increases the error in crystal frequency. To minimize spurious radiation, push-pull tripler stages similar to those of Figure 2 were used wherever possible in the transmitter. This gave a multiple advantage. First, even-order harmonics are cancelled out by the push-pull action of the tube. Second, the operating frequencies of successive stages are separated enough so that circuit constants can be selected to obviate the possibility of tuning to the wrong harmonic. Third, the use of push-pull circuits with a small amount of positive feedback enables tubes of low rating to operate at high efficiency.

Three tripler stages and a buffer amplifier of conventional design give a multiplication of 27 times to arrive at a frequency of approximately 160 megacycles, as shown in Figure 1; at frequencies much higher than this, conventional circuits have low efficiency and generally are not used. The two final multiplier stages of the transmitter use re-entrant coaxial circuits as tuned elements and utilize tubes that have very low interelectrode spacing and capacity and a mechanical configuration which permits convenient application to coaxial tank circuits. The first of these tubes is a tripler stage having an output frequency of approximately 480 megacycles, and the second of these tubes is a doubler stage having an output in the 940-to-960-megacycle band.

The mechanical construction and a roughly equivalent schematic circuit for the last two stages of the transmitter is shown in Figure 3. Tubes, circuit constants, and operating



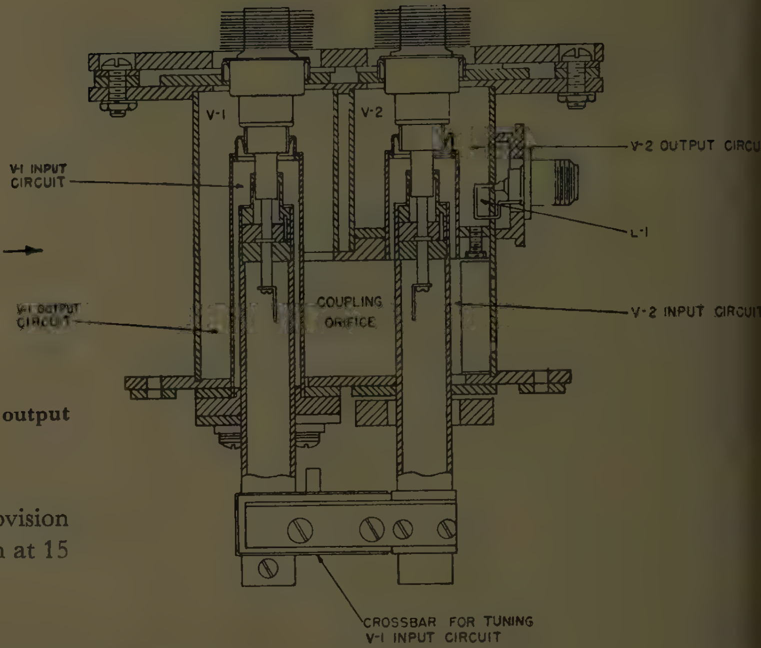


Figure 3. Outline and equivalent schematic for driver and output stages of microwave transmitter

voltages were selected to give five watts' output. Provision was made, however, in the design to permit operation at 15 watts' output where desirable.

PROPAGATION AND ANTENNAS

At microwave frequencies, transmission usually is limited to line-of-sight paths. With unity-gain antennas, the transmission losses even with line-of-sight paths are very high and would require very high-power transmitters to get even short-range operation. It is possible to get economical transmission over reasonably long distances because of two factors. Because of the short wavelength, it is possible to build relatively small antennas having high

Figure 4. Crysta diode used as mixe in input stage c microwave receive

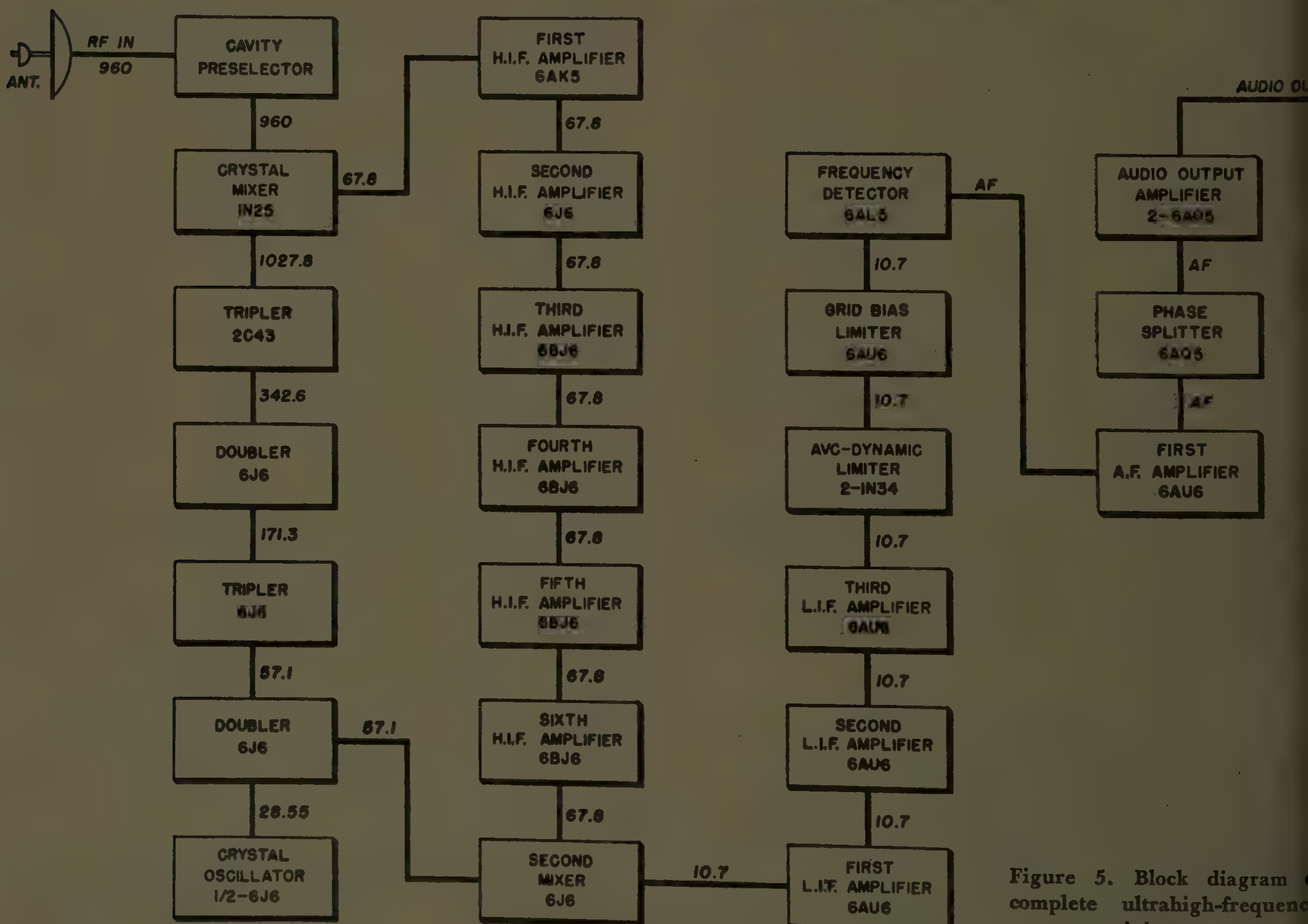


Figure 5. Block diagram c complete ultrahigh-frequenc receiving system

er gain since the gain of an antenna is proportional to ratio of its area to the square of the operating wave- th. The use of such high-gain antennas, both for smitting and receiving, effectively increases the power out of the transmitter. Also, at microwave frequencies e is practically no man-made or natural static; this bles satisfactory signal-to-noise ratios to be obtained at al levels much lower than is practical at lower frequen- .

ormulas showing the relation between free-space path and antenna gain are given in other papers.[4,5] It can hown that increasing the size of antennas used decreases apparent path loss between communications terminals. lowever, if the path loss, even with relatively large an- nas, is compared with the loss experienced over com- able distances with power-line carrier, it is seen that e is a very great difference. A simple example will strate this.

960-megacycle microwave system operating over a 20- path with $3^1/_2$-foot-diameter antennas will have a l path and coupling loss of about 100 decibels. A ver-line carrier system operating over a 20-mile-long nsmission line will have a total path and coupling loss of order of 20 decibels. If the noise voltage level at the in- of the receiver were the same in each case, the microwave nsmitter output would have to be 80 decibels or 10,000 es as great to give the same signal-to-noise ratio at the ut to the receiver. Actually, there is little noise at rowave frequencies and the limiting noise is usually that erated in the microwave receiver itself. This enables ration of microwave equipment over considerable dis- ces with transmitter power outputs which are of the same er as power-line carrier transmitter outputs. It does an, however, that the gain of microwave receivers has to many times as great as that of carrier receivers with a ltant increase in complexity and number of tubes.

he type *FB* microwave equipment is designed to operate a path loss between transmitter output circuit and re- ver input circuit of up to 125 decibels. A wide range of s of antennas and types of coaxial cables for intercon- tion with the equipment is available so that the most nomical installation can be worked out.

RECEIVER NOISE CONSIDERATIONS

T MICROWAVE FREQUENCIES the predominant noise is that generated in the receiver itself. Most of this re- ver noise is generated in the first high-gain stage of the eiver. It is important, therefore, to give serious study to design of these stages. Amplifiers operating at micro- ve frequencies usually have poor noise characteristics, king it desirable to convert the microwave signal to a er frequency by means of a low noise converter and then se amplifiers having better noise characteristics to do the plification. A synthetic crystal diode is usually used as a er in the input circuits of microwave receivers to convert microwave frequency to a much lower frequency.

n the type *FB* microwave receiver, a type *1N25* crystal ing low noise figure and good overload characteristics is d as a mixer. This crystal, which is housed in a car- ge, is fed a signal from the receiver antenna and from a crystal-controlled local-oscillator multiplier chain, as shown in Figure 5. This local-oscillator signal, which is about 67 megacycles higher in frequency then the incoming signal from the antenna, is mixed with that signal in the crystal detector. The output from this mixer contains the input frequencies, sums and differences of the input frequencies, and harmonics of the input frequencies. A tuned amplifier, indicated as the high-intermediate-frequency amplifier on Figure 5, amplifies the difference frequency which is about 67 megacycles.

The first two stages of the high-intermediate-frequency amplifier are connected in a circuit which has the low noise characteristic of a triode and the high gain characteristic of a pentode tube.[6] These two stages effectively act as the first high-gain stage of the receiver and their low noise figure gives the entire receiver a low noise output.

RECEIVER SPURIOUS RESPONSE

SINCE A crystal or other mixer having a very wide frequency response is used in the input circuits of most microwave receivers, there is danger of undesired signals

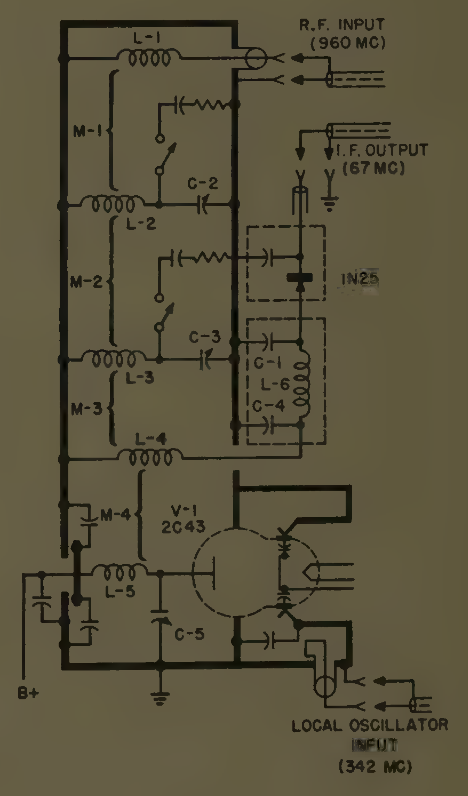


Figure 6. Equivalent schematic of microwave receiver input circuits including tunable preselector and crystal mixer

being accepted by the receiver and producing interference or unsatisfactory operation by saturating the input circuits so that the desired signal is not received.

In the type *FB* receiver a tunable-cavity-type preselector is used in front of the mixer crystal. This preselector, the last multiplier stage of the local-oscillator multiplier chain, and the crystal mixer are shown schematically in Figure 6. The upper portion of Figure 6 enclosed in the heavy lines represents the preselector. The lower portion is the multiplier stage of the local-oscillator source. The incoming and local-oscillator signal are fed by *L-4* to the crystal mixer.

To give increased protection against the likelihood of undesired signal at frequencies higher than the desired one getting through to the mixer, an additional low-pass filter comprising *C-1*, *L-6*, and *C-4* is included in the circuit to the mixer. Laboratory tests on type *FB* receivers show that rejection of spurious signals is greater than 70 decibels.

RECEIVER GAIN

THE HIGH PATH attenuation and low noise at microwave frequencies make it possible to operate with satisfactory signal-to-noise ratios with very low input signals. In order to get maximum range, these very low input signals must be amplified to a usable level and thus the intermediate-frequency amplifiers of microwave receivers must have very high gain. In the design of amplifier for microwave receivers using pulse or other wide-band modulation, it is not possible to realize a large gain per stage for two reasons. First, the gain per stage must be kept low enough to prevent oscillation due to feedback through tube interelectrode capacity. Second, for a given tube type and circuit, the product of gain and bandwidth is a constant. For a *6AK5* tube, this gain bandwidth product is approximately 62 megacycles per second, which means that for a bandwidth of six megacycles a gain per stage of only ten could be realized. In any tube, the gain bandwidth product is given by $Gm/2\pi C$, where C is the sum of input and output capacity of the tube and stray capacity of the circuit.

In the type *FB* microwave receiver, a total gain of 90 decibels in the high-intermediate-frequency amplifier and 70 decibels in the low-intermediate-frequency amplifier is obtained. The 67-megacycle strip has a bandwidth of 1.2 megacycles and the 10.7-megacycle strip has a bandwidth of 0.3 megacycle.

In the design of such high-gain amplifiers extreme caution has to be taken to provide safeguards against oscillation. Lead lengths must be kept to an absolute minimum. The importance of this is illustrated by the fact that a 1-inch length of Number 20 wire has a reactance of eight ohms at 60 megacycles. In the type *FB* receiver each intermediate-frequency amplifier uses a separate subchassis designed to keep lead lengths down and to act as a section of waveguide operating below cutoff frequency in order to attenuate feedback which is actually radiated from one circuit to another in the amplifier.

RECEIVER INPUT VARIATIONS

IN MICROWAVE SYSTEMS there usually are relatively wide variations in receiver input levels due to differences in path lengths, multipath transmission, and other causes. In practically all systems, some device is used to keep the input to the detector of the receiver essentially constant. On frequency-modulated receivers, these amplitude variations could be eliminated completely without any loss of intelligence and, in fact, should be eliminated for low-distortion output from discriminators and other frequency detectors. These amplitude variations are removed in frequency-modulated receivers by a limiter. This limiter can be either one or two stages, with the 2-stage type usually preferred.

In the type *FB* receiver, a 2-stage limiter is used. The first limiter stage utilizes *1N34* crystals and the second is a grid-bias type having a very short time constant to enable it to remove the very-high-frequency amplitude modulation caused by adjacent channel signals.

DETECTORS

THE TYPE OF detector used in a microwave system depends, of course, on the type of modulation used. Generally speaking, however, the much greater signal bandwidth used and the necessity for eliminating harmonic products and intermodulation of the multiplicity of signals which may be transmitted over a single channel demand very great care in the design of detectors. System distortions of the order of four or five per cent which are ordinarily acceptable with low-frequency-equipment would cause prohibitive intermodulation and crosstalk on many microwave equipments. Pulse-time, pulse-width, and pulse-code modulation schemes are completely different in philosophy to the schemes normally used in low-frequency equipment and therefore require completely different types of detectors.

In the type *FB* receiver, the incoming signal is of the frequency-modulation type. The frequency detector is designed to have excellent linearity out to ±400 kc over wide variations in temperature. The distortion in a complete system consisting of a type *FB* transmitter and a type *FB* receiver is less than one per cent.

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Electronic Iron Cores Standardized

All types of electronic cores made from iron powder and commonly in use by the radio and television industry have been listed in a new standard released by the Metal Powder Association. The standard was prepared by the Electronic Core Subcommittee of the Metal Powder Association Standards Committee to meet a need long felt in industry for standardization of the dimensions and tolerances of electronic cores. The standard, designated *11-51T*, defines the terms commonly associated with electronic cores made from powdered magnetic materials and specifies the preferred dimensions of standard sizes and shapes. Preferred dimensions are listed in detail for plain iron cores, insert iron cores, threaded iron cores, tuning cores, and sleeve iron cores. Data are provided also for concentricity, screwdriver slot dimensions, and hexagonal hole sizes as well as threaded-spring type and spaded-insert sizes.

Insulation Field Test Results

W. F. DUNKLE
MEMBER AIEE

WELL-PLANNED execution of a practical test program results in a maximum of equipment-operating ficiency through utilization of a minimum of test man ɔwer, equipment, and expense. The objective is to etermine the extent of insulation deterioration and then ke remedial measures against failure of the equipment.

A successful program must employ test equipment versa-le in application, with a wide range of current voltage lues, and instrumentation with sensitivities from a few icroamperes to an ampere. Ranges of 500 to 10,000 olts are satisfactory for a-c and d-c testing. A-c test uipment is used for the majority of testing; d-c test uipment has been supplemented by an amplifier recorder hich reduces dielectric-absorption testing time by 43 per ent.

Test equipment must be mobile, comfortable for the erator to use, and have all-around visibility. Accurate sults should be secured in a minimum of time.

The Pennsylvania Power and Light Company has been sing a test program for 17 years. Equipment failures used by deteriorated insulation have been largely elimi-ated, and equipment on the verge of failure has been reha-litated and put back into service.

To establish criteria for classifying the condition of sulation, it has been necessary to accumulate data over an tensive period of time. Comparison of the results of any tests on identical or similar apparatus is used to detect eterioration. In addition, the establishment of base lines as been facilitated by the pooling of data from a large umber of power companies that have similar test programs.

Common sense and a willingness to take responsibility on e part of the insulation test engineer are necessary to the ogram's success, for much depends upon the personnel ho carry on insulation testing. Because the test engineer alyzes results and makes remedial recommendations on e spot at the time of tests, firmness concerning curative easures, intelligence, and technical education are some of e requirements for a test engineer. He must have orough knowledge, theoretical and practical, of insulation ehavior in relationship to temperature, structure, com-osition, voltage, and frequency.

DISCUSSION

THERE HAVE BEEN arguments for and against the worth of both the a-c and d-c tests. It is not the intent of this ticle to prove the merits of either, but to show what has een done with an inclusive test program.

Since the economics of the program was based upon lvage-rehabilitate, careful records were maintained on savings resulting from the program. These data are given in Figure 1. During the interim of World War II, had it not been for the ability to recondition insulation and control the results, the company would have been in a serious position. It has been said that combined like programs among the respective utility groups resulted in a net saving, from 1941 to 1945, of $60,000,000 to $75,000,000 in strategic equipment.

A large number of instrument transformers were found defective; this is typical of dry-type insulation where voids

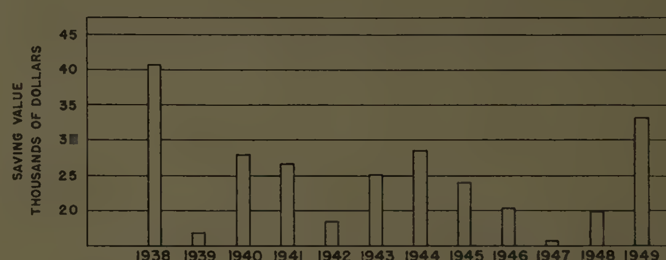

Figure 1. Savings made by rehabilitation of bushings

are readily created and air is trapped in high electrical stress areas. Power transformer defects increased perceptibly in 1949. Many of these transformers were old, due for inspection and overhaul, and had been worked higher than rated during the strategic materials shortage.

CONCLUSIONS

THE METHODS and test equipment described for determining apparatus fitness for service insures a quality which is satisfactory and results in an economy that cannot be treated lightly.

The simplicity of operation, uniformity of presentation of data, and speed of testing and analyzing results are essential requisites, considering the high cost of equipment outage today. These factors make it most desirable for accuracy and for production testing in the field.

Failure rates in excess of four per 1,000 bushings are indicative of something being wrong either with personnel, criteria, schedule, or reluctance to carry out remedial measures. Interruptions caused by failure of deteriorated bushings are no longer excusable.

A careful evaluation of failures is essential to learning the facts concerning the cause of field failures.

The personnel are a very important part in the efficacy obtained using like equipment.

Transportation must be comfortable, fast, and have all-around visibility and excellent interior lighting to insure precise instrumentation.

Results of tests must be analyzed immediately, and any corrective measures required should be instituted at once.

gest of paper 51-43, "Insulation Field Test Results," recommended by the AIEE mmittee on Instruments and Measurements and approved by the AIEE Technical ogram Committee for presentation at the AIEE Winter General Meeting, New rk, N. Y., January 22–26, 1951. Not scheduled for publication in AIEE *Transions*.

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Transmission Matrix Stability Criterion

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MEMBER AIEE

AMONG THE methods for predetermining the stability of networks—that is, whether or not self-sustained oscillations may exist—the Barkhausen and Nyquist criteria often are applied to those configurations employing electron-tube amplifiers for which a principal closed transmission loop may be delineated. In these networks the concept of "retroaction" or feedback is useful, since this provides a mental picture of a signal progressing unidirectionally through the electron tube, the feedback network, back to the tube input, and so on. It also leads to a simple scheme for computing the ratio (often denoted by $\mu\beta$) of output to input voltage for the open transmission loop, upon which the stability of the network apparently rests. However, these criteria are limited to unilaterally transmitting networks, and the determination of $\mu\beta$ must be made, in effect, with the transmission loop cut at zero admittance grid-cathode terminals of an electron tube.

A more general criterion for stability of a closed transmission network is given by the expression

$$A(\lambda)=a_{11}{}^0+a_{22}{}^0-|a^0|-1=0 \qquad (1)$$

Equation 1 may be called the generalized transmission matrix stability criterion. It represents the sum of the terms on the principal diagonal of the over-all open-loop transmission matrix $[a^0]$, minus the determinant $|a^0|$ of the same matrix, minus 1. In general, since $[a^0]$ is a function of the complex frequency $\lambda = \sigma + j\omega$, it follows that the generalized criterion $A(\lambda)$ is also a function of λ. Furthermore, the network will oscillate spontaneously upon closing the transmission loop for those complex frequencies which are roots of equation 1 and have positive real parts.

The criterion is derived from the over-all transmission matrix $[a^0]$ of the network, which may be represented symbolically by Figure 1, and in which the feedback loop has been opened at an arbitrary point. The associated over-all transmission matrix equation for the network is

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix}=[a^1]\cdot[a^2]\cdots\cdots[a^n]\cdot\begin{bmatrix} E_n \\ -I_n \end{bmatrix}=[a^0]\cdot\begin{bmatrix} E_n \\ -I_n \end{bmatrix} \qquad (2)$$

in which the $[a^i]$ may contain linear electronic or electromechanical amplifiers or other linear circuit elements. The transmission matrices are defined in the usual way; for example, $[a^1]$ relates terminal variables for the first network in the loop by the scheme

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix}=\begin{bmatrix} a_{11}{}^1 & a_{12}{}^1 \\ a_{21}{}^1 & a_{22}{}^1 \end{bmatrix}\cdot\begin{bmatrix} E_2 \\ -I_2 \end{bmatrix} \qquad (3)$$

with polarities defined as shown in Figure 1.

Now it is clear that the network will be on the threshold of instability after the transmission loop is closed, if

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix}=\begin{bmatrix} E_n \\ -I_n \end{bmatrix} \qquad (4)$$

for the open loop. That is, if the complete signal is transmitted through the entire loop with zero gain or loss, and zero phase shift.

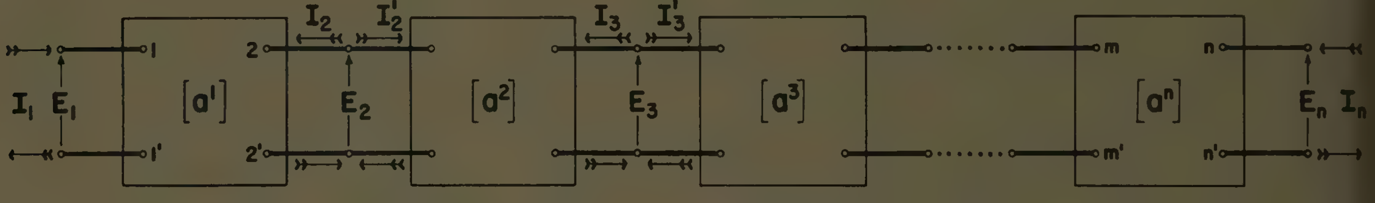

Figure 1. Symbolic representation of a transmission loop opened at an arbitrary node pair

Substitution of equation 4 into equation 2 then yields the generalized criterion, equation 1.

If the transmission loop is cut at the zero-admittance grid-cathode of an electron tube, which is a unilateral amplifier, then the criterion given by equation 1 reduces to

$$a_{11}{}^0-1=0 \qquad (5)$$

This is equivalent to the Nyquist criterion

$$\mu\beta-1=0$$

An analogous criterion applicable to a transmission loop cut at the zero impedance control element of a unilateral amplifier is

$$a_{22}{}^0-1=0 \qquad (6)$$

The generalized criterion given by equation 1, on the other hand, applies to transmission networks with unilateral or with bilateral transmission properties, and the transmission loop for which the matrix coefficients are computed may be cut at any desired point at will without regard to impedances in either direction from the cut.

Digest of paper 51-46, "The Generalized Transmission Matrix Stability Criterion," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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The Renaissance in Electrical Education

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The electrical engineering curriculum of 25 years ago is compared with that of today. The differences in 60-cycle and high-frequency training are presented and stress is laid on the need for training of electronics in the fundamental area.

THE ENGINEERING method calls for the collection of all available data on a subject and ie drawing of logical conlusions therefrom. When is method is applied to a udy of the electronic material hich is taught in electrical engineering education, one nmediately finds that there are no facts, only opinions, situation such as one frequently meets in a problem in ie social sciences. However, there are certain helpful ources of information which can be drawn upon; namely, ast history and experience. This area is one which our resent-day social scientists seem eager to overlook in udies in their own field. Certainly if experience is of alue to a practicing engineer, it also should be of value a practicing teacher. Just as the practicing engineer nay know intuitively that the decimal point is in the orrect place for a particular design, so too should the eacher use experience to avoid repetition of past errors nd difficulties. It is fitting that we choose the present ioment to look at past experience in electrical engineering eaching, since we are now approximately at the golden nniversary point in formal college education in electrical ngineering, the first degrees having been granted in ppreciable numbers in this country around the turn of ie century.

ANALYSIS OF BASIC KNOWLEDGE

FROM AN EXTREMELY fundamental viewpoint, it probably can be said that there have been almost no additions our basic knowledge of electricity since the beginning f this 50-year period of education. There have been, f course, advances in application and in new techniques, ut it can be stated with reasonable completeness that our asic knowledge was nearly all available about the year 900. For example, Ohm's work around 1830, Coulomb's w from 1785, Ampere's law derived from work in the 820's, Faraday's induction law om 1831, Maxwell's equations om 1864, the work of Heaviside nd others on lines, the photoelecric effect, electromagnetic radiation, nd the discovery of the electron in the late years of the 19th century gave us the fundamentals on which we now build our electrical education. Therefore, changes and new methods introduced in education in this 50-year period can be looked upon as due to the ingenuity of engineers and educators in developing new methods, or to the demands of the field for graduates better trained in new areas, and not to the development of a large amount of new fundamental knowledge.

ENGINEERING CURRICULUM OF 1925

OF THE PAST 50 years in electrical engineering education, it might be said that the first 25 were spent in the study of the machine, the building of a background of information concerning it, and the development of teaching methods suited to it. The evident direction of this concentration of interest is well illustrated by a summary of the curriculum in electrical engineering as followed by one of the leading universities in 1925. See Table 1.

One need look only at the column headed "Electrical Engineering," where 24 out of a total of 38 semester hours of credit are given to the machine and machine design, to see the concentration on machinery as of that date. Only six credit hours are given to the electric circuit where the machine was to work.

Those with experience as a teacher or student of 1925 may well remember the text books which on page one stated:

$$i = I_m \sin \omega t$$

and thereby lost the instantaneous and nonsinusoidal area completely, never to be discovered by the student until that rare day at the end of the course when he was introduced to a realm of pure fantasy called "transients," things that were nice to know about but which supposedly were met rarely face to face in engineering practice, so the

Table I. Electrical Engineering Curriculum Circa 1925

Basic		Nonengineering		Other Engineering		Electrical Engineering	
Chemistry	8*	English	6	Thermo; Steam Power	8	Circuits	6
Drawing	8	Foreign Language	9	Mechanics	11	Power Meas.	5
Mathematics	19	Elective	8	Shop	9	Machines	18
Physics	9					Design	6
						Tech. Elective	3
	44		23		28		38

* All figures are semester hours.

ssential text of a conference paper recommended by e AIEE Committee on Education and presented at e AIEE Winter General Meeting, New York, . Y., January 22–26, 1951.

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teachers said. They forgot to mention that if you ever did meet one it was possible for it to wreck you, your machines, or your company in a matter of a few thousandths of a second.

There were also the electrical engineering books which passed over the a-c circuit in a brief chapter in the rush to get to the machine. The books of that era usually assumed that $Z=\sqrt{R^2+X^2}$ was the ultimate goal, and the writing of electromotive force equations, the solution of circuits more complicated than an Edison 3-wire system, or the use of equivalent circuits were matters believed not worthy of much time. It should be mentioned that a little, imaginary thing called "j," used in a weird algebra called "complex," was just being introduced in the early 1920's, and the books of the day possibly can be excused for a few of their deficiencies in this direction.

The magnetic field was covered in a simple treatment with the materials restricted to cast iron, cast steel, and annealed sheet steel—materials which some of our modern books still seem to consider as the only ones of importance. The electric field was passed over with discussions of energy storage in a capacitor, and possibly a discussion of insulator breakdown. Lucky was the student of that day whose instructor insisted that he understand thoroughly the definition of electric field intensity and the meaning of electrical potential.

It is interesting to note that the curriculum shown in Table I indicates little time or interest in the things we now consider humanistic-social, giving to nonengineering electives slightly less time than to courses in machine shop, woodworking, and foundry. Are graduates of curriculums like this numbered among the alumni who are now calling for broadened engineering curriculums for today's students?

ENGINEERING CURRICULUMS OF 1950

A MORE OR LESS typical curriculum of 1950 is presented in Table II in order that we may appraise changes made in the second 25 years of the half century.

Table II. Approximate Electrical Engineering Curriculum Circa 1950

Basic		Nonengineering		Other Engineering		Electrical Engineering: Power Option		Electrical Engineering: Electronics Option	
Chemistry	8*	English	6	Thermo	3	Circuits	14	Circuits	22
Drawing	8	Speech	3	Mechanics	8	Machines	14	Machines	8
Mathematics	20	Economics	6	Heat Power	3	Electronics	8	Electronics	13
Physics	10	Personnel Adm.	3	(Power Option)		Transm.	6	Elective	6
		Other	8			Elective	5		
	46		26		11 or 14		47		49

* All figures are semester hours

During this second 25-year period, the presence of radio or more broadly, electronics, made itself felt, and while it cannot be said that this was the only influence acting to create differences between the curriculums, it certainly can be considered as one of major importance. It should be sufficient merely to discover that changes have been made to allow us to reason by Newton's second law that some force or forces have been at work.

It is interesting to note that the basic area remained almost unchanged in percentage of time allotted to it. This is not to be construed as a lack of change in course material, since physics has altered and mathematics has been expanded to include differential equations. A very significant change appears under the heading of "Other Engineering" with the complete disappearance of the shop courses of 1925, and some reduction in the work in steam and steam-power apparatus. The nonengineering area shows only a small increase in hours but a significant change in the types of courses required, indicating some awareness among engineering teachers that their graduates must rub shoulders with people, which was not indicated too well with respect to the 1925 designations of English and a foreign language.

CHANGES IN CURRICULUMS SINCE 1925

THE MAJOR CHANGE appears in the electrical engineering courses, with the appearance of two student choices or options instead of the previous one. The area of circuits also has been increased radically in importance even for the power option. Circuits are essential to the study of electrical engineering and a machine is a circuit first, and becomes a machine by addition of certain elements, which can even be treated as additional circuit elements if desired. If the first 25 years of electrical engineering education was given to the machine, it certainly can be said that the second 25 years show the ascendancy of the circuit.

The real difference between 1950 and 1925 electrical teaching does not appear with a mere comparison of curriculums of the two dates. The factor of great significance is the renaissance or resurgence of the basic fundamental laws of electricity. This is indicated through the greater awareness of people teaching in both the power and electronic fields of the significance of our basic knowledge such as Coulomb's law, Ampere's law, Faraday's law, and Maxwell's equations, and their present-day abilities in applying these basic laws.

Our teaching of the present day must be suitable for all frequencies, not just one or two. It must be able to handle nonsinusoidal quantities as well as sinusoidal quantities. We must treat quantities as variables in general and constants in special cases, rather than as constants with variability as the special case. We must recognize nonlinearity and learn to handle it rather than to shrug our shoulders and treat all elements as linear.

We must treat Lenz's law as the force on a current, not the force on a conductor. The rms volt must appear as a convenient mathematical fiction, not as a circuit entity, since, to an electron, an rms volt is of no concern. Self-inductance must be defined from $e=d(Li)/dt$ rather than from Lenz's law, and capacity through the displacement current, $i=dq/dt=d(Ce)/dt$, since concepts of L and C must be fundamental if it is to be possible to recognize L and C when encountered in circuits without lumped parameters. The sinusoidal assumptions and superposition

ory which underlie our usual circuit analysis must not subordinated so that they become lost, as was too often case in 1925.

PRESENT-DAY TEACHING METHODS

LL THIS MAY be summarized in a statement concerning one major advance of the 25-year period—good sent-day teaching is done with full knowledge, and not lect, of the underlying assumptions.

s an example of difference in viewpoint, consider the nsformer or coupled circuit of Figure 1, in which the ondary side is connected to a capacitive load. If this cuit were shown to a student in 1925, he probably would e stated unhesitatingly that with a secondary capacitive d the impedance seen on the primary side would have n capacitive. However, if one takes a more general pled-circuit viewpoint, it is possible to show the student 1925 quite wrong for certain values of capacitance. sent-day students certainly would be in a position to agree with the student of 1925, not because they are essarily better intellectually but because they have n given a circuit viewpoint with a broader base. This wpoint has objectives which must be different than se of 1925 because of the much greater demands made on our electrical engineering graduates as of the present . A plot of the input impedance of the transformer inst C indicates that the answer of the 1925 student is rect only in one region of the performance plot and regards certain other effects which may arise. It was presence of these other unexpected effects which so quently disconcerted power engineers when they began dabble in radio in the 1920's. They had studied elec-cal engineering under a condition of single-frequency cialization and that cannot be tolerated at the present e. It is now necessary to teach on the basis that it is ter to disregard a term in an equation than not to have own of its presence. This frequently represents the ference between the right answer and the wrong.

Because of the availability of the fundamental knowl-ge, it might be reasoned that as good a job of teaching uld have been done in 1925 as in 1950, but it can be ted categorically that it was not done. The reasons for s are not self-evident, but at least two can be stated: lack of attention to fundamentals which the 60-cycle cialization had brought on, and the lack of great demand m industry for more fundamentally trained graduates that time. Our great upsurge of research and develop-nt had not yet begun; industry's desires were for esmen and designers, not research or development men, d the colleges catered to the demand. When a new aduate was hired, he was not placed in a position which uld tax his abilities but in one in which he frequently t those abilities through lack of use. This is still true some industries which fail to take advantage of the full hnical level to which our graduates are now trained.

IMPORTANCE OF ELECTRONICS COURSES

THE INTRODUCTION of electronics into the field has per-formed one great service and this is in itself a very strong argument for thorough teaching of the basic areas in electronics. An electronics course presents great possi-bilities for teaching prior work by repetition. The tech-nique of a survey course followed by a series of more intensive courses over the same area hardly can be justified under the time limitations imposed by the present engi-neering curriculums. However, that does not mean that teaching by repetition, so common at lower learning levels, need be lost. Repetition of previous subject matter and

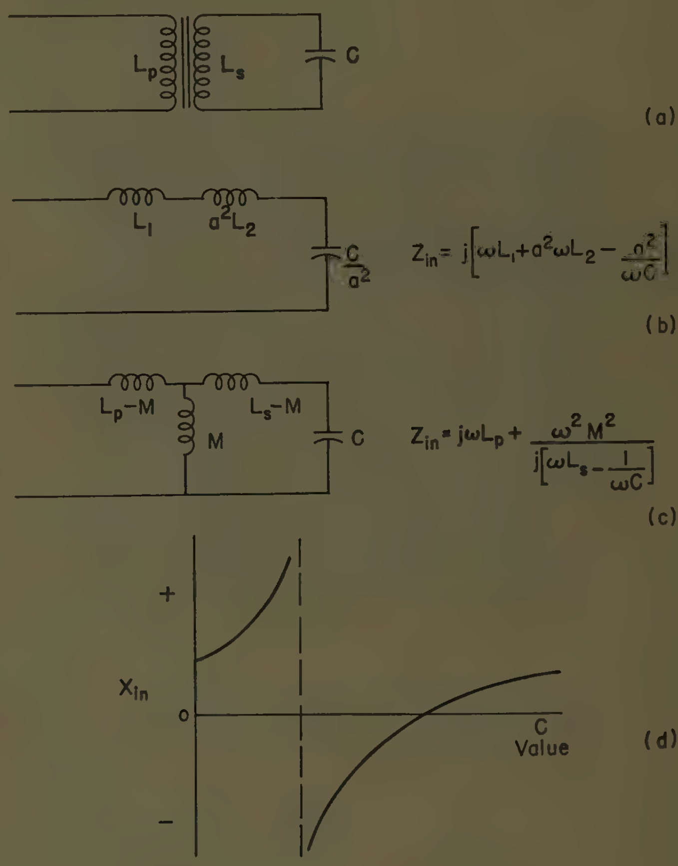

Figure 1. Simple circuit illustrating modern approach to circuit analysis

ideas, when employed in the learning of new material, is good and can be achieved without waste of time. In fact, it may be a better teaching method than straight repetition since the student's interest can be maintained more readily. This method might possibly be called repetition by application.

As an example, consider the basic electronics course as taught in many schools. Such a course might include work in charged-particle ballistics, tube characteristics, equivalent circuits, gaseous conduction, and gas tube application. It will be found that the treatment of ballistics is excellent for repetitive learning of dynamics which the student previously studied in his mechanics courses. As soon as the student acquires the idea that ballistics is nothing but an application of his dynamics, he often is enthused to find an application of what may have been to him a barren theoretical area. A study of tube characteristics then becomes additional teaching in

graphical methods of circuit analysis. The equivalent circuit for the vacuum tube serves to reinforce the student's learning in a-c circuits. In fact, students who are poorly prepared in a-c circuits usually will tend to have difficulty at this point in the electronics course.

Gaseous conduction repeats and strengthens many ideas of atomic structure gained in chemistry. The study of gas tubes and gas tube circuits gives the student practice in the handling of nonsinusoidal waveforms and refreshes his understanding of average and rms values through the necessity to use these computations in their most basic form.

Repetitive teaching in this manner is good and involves no additional time. The introduction of electronics into the curriculum, therefore, has served a very useful purpose above that expected in the teaching of electronics alone.

BASIC PRINCIPLES OF ELECTRONICS

THE ELECTRONICS and radio areas may be divided into three major parts: the physical background of the vacuum tube, the characteristics of the tube itself, and the circuit in which the tube must operate. Adequate preparation for engineering work in the electronics and communications field should include coverage of all three of these areas.

No one can say that electronics is through developing or that all possible types of tubes have been invented. Therefore, our graduating electrical engineers need an understanding of the basic physical principles of electronics in order to understand the operation of new types of tubes as they are invented in the future. The student of 1935 graduating without a proper physical background probably has had great difficulty in understanding the operation of the multicavity magnetron, the klystron, the phasitron, the iconoscope, and the image orthicon, to mention only a few. Our present graduates should not be placed in such a position with respect to future developments in the electronics field. In other words, let us not place them in the position of a confirmed 60-cycle man when told of power transmission through a waveguide.

A careful study of the tube and its characteristics must be made because the tube is inherently a nonlinear device. Frequently it may be the first such device encountered by the student in his engineering training and is ideally suited to such study because of the romantic aspects of the tube—that feeling of almost obtaining something for nothing which has stimulated men's imaginations to achieve as much from as little as possible. The vacuum tube is considered as linear for many applications, yet it is to be hoped that the inherent nonlinearity will never be overlooked, and that the assumptions underlying linearity will always be apparent to the worker.

The consideration of the circuit in which the tube is to work introduces new concepts in circuit analysis, many of which are based on treatment of circuit performance over a wide band of frequencies, a treatment possibly foreign to the student's previous experience. The use of tuned circuits for frequency selection and the proper design of these circuits for maximum voltage or power output, the idea of maximum power transfer as against the machiner viewpoint of maximum efficiency—all these items go wit a course in electronics.

Another concept which should not be overlooked i that of the employment of the nonlinear characteristics o the tube to a useful end as appears in modulation an demodulation in some types of circuits. In other types o demodulators and in class-B and -C amplifiers, the studen becomes aware of circuits with discontinuous current flo and the difficulties in their analysis.

At the higher frequencies circuit performance an design becomes a function of tube design in that the tub and circuit must be considered as a permanent partnership This calls for a firm understanding of field theory as wel as a knowledge of tube design. Field theory is also neces sary in the teaching of radiation; a physical phenomeno without which most radio engineers would be withou jobs today.

OTHER PRINCIPLES OF ELECTRONICS

IT MAY BE NOTED that the design and operation of complet receivers and transmitters, or other complete com munication systems or industrial electronic devices, hav not been mentioned as necessities. This is because i is felt that the basic principles and the understanding o them are the business of the university; that, given thes basic principles, a graduate engineer will quickly under stand receivers, transmitters, and industrial devices Without these basic principles, a graduate engineer remain at the level of the radio serviceman or the laborator technician, both of which are desirable occupations, but the are not the ones for which universities should be train ing engineers.

FUTURE OBJECTIVES

IN CONNECTION with the objectives of a modern electrica engineering curriculum, the writer at one time had th opportunity of hearing Karapetoff of Cornell Universit classify workers in the scientific field into four broa groups: technical technicians, practical technicians, tech nical practicians, and practical practicians. If any on conclusion can be drawn from the comparison of th curriculums in electrical engineering of 1925 and 195 it is that the objectives of those curriculums have been raise by at least one level in that period of 25 years.

In 1925 the graduates in electrical engineering we well trained for positions which might fall under the secon of the classifications just mentioned, namely, that of th practical technician. It is felt that in the last 25 yea the sights have been raised and the level of our graduat is now at or near that of the technical technician. Whi approaching the top classification, it is to be hoped th this is also not an approach to a plateau or leveling-o region in objectives.

Electronics must remain true to its fundamentals an not fall into an era of overspecialization. If that shoul happen, then it is to be hoped that some new area electrical technology will arise and continue to stimula the electrical engineering field for the next 25 years electronics has done for the last 25.

A Complex Wave Synthesizer

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'HE USE OF Fourier's method for analysis of complex waves, whether they be electric, mechanical, or aural aature, is well known. A device which could produce ariety of complex waves could be used to check tedious aputations or even to apply a desired complex wave a system in order to observe its response. Such a device ae subject of this article.

'his device must be able to produce a number, ten is ally sufficient, of harmonically related sinusoidal quencies, variable in amplitude and phase angle.

'he method of producing these frequencies utilizes the t that in a series circuit composed of a d-c source, a uum photoelectric cell, and a resistor, the voltage p across the resistor is directly proportional to the ount of light falling on the photoelectric cell. By ying the amount of light sinusoidally, a sinusoidal tage is produced. A rotating disc was placed between hotoelectric cell and a constant source of light whose iphery was cut so that the radius varied sinusoidally to e the properly varying amount of light. A generator this type was made for each harmonic frequency by ating all the discs at about 1,800 rpm and cutting three e waves on the first, six on the second, nine on the third, l so forth.

'o vary the phase angle the pickup assembly, consisting a lamp and a photoelectric cell, of the fundamental quency was made stationary while the pickup assemblies

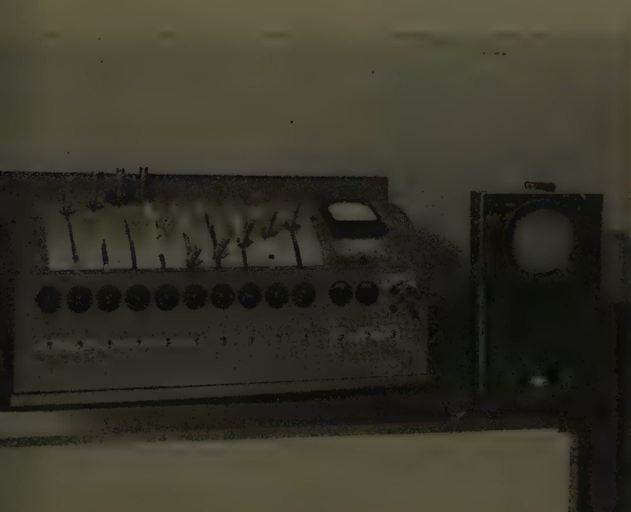

Figure 1. Front view of the synthesizer

the harmonics were designed to be moved along the iphery of their respective discs a distance equal to the gth of one sine wave. The angle through which each kup assembly must move varies from 60 degrees for the ond harmonic to 12 degrees for the tenth harmonic. These assemblies were connected, through suitable gears, to handles which moved through an angle of 60 degrees. Scales under each handle were calibrated from -180 degrees to $+180$ degrees in 5-degree intervals.

To control the amplitude of each harmonic the resistor

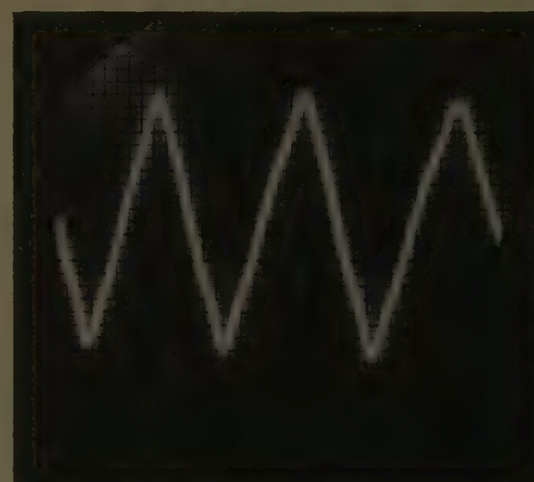

Figure 2. Triangular wave produced by the synthesizer

used in series with each photoelectric cell was a potentiometer. The output voltages of each harmonic generator then were combined through a series of mixing circuits so that a final output was obtained which was proportional to the sum of the individual output voltages. For calibration purposes, it was arranged so that the supply voltage could be removed from all of the photoelectric cells and then be applied to each photoelectric cell independently. The amplitude of each harmonic, as read by a voltmeter across the mixer output terminals, then could be adjusted to the desired level.

The complex wave synthesizer fulfilled its requirements reasonably well. The discs, being hand made, do not produce exact sinusoidal voltages. However, the accuracy is sufficient for most purposes. The phase-angle calibration is accurate to within 2.5 degrees, which is one-half of the smallest scale division.

It is evident that, besides the scientific uses, the synthesizer can be used by mathematics, physics, and engineering teachers to forcibly demonstrate the validity of Fourier's theorem and Taylor's theorem. It also can be used as a teaching aid in problems involving complex waves because it eliminates most of the imagination required by the student in the visualization of these problems.

Digest of paper 51-179, "A Complex Wave Synthesizer," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Great Lakes District Meeting, Madison, Wis., May 17–19, 1951. Not scheduled for publication in AIEE *Transactions*.

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A New Train Performance Calculator

S. V. SMITH

PRIOR TO the acquisition of new or improved types of railroad motive power and at times when track or other improvements are contemplated, it is customary to calculate the performance of a typical train over a specified route. The usual step-by-step calculations of train performance are tedious and require considerably more time than a train would need to operate over the same route.

A new train performance calculator recently placed in service by the Pennsylvania Railroad in Philadelphia, Pa., was developed to compute and record train performance in actual train time. This calculator consists of three self-balancing potentiometer-type curve-drawing instruments, electrically interconnected, and a low-energy auxiliary circuit, all of which are mounted on two self-supporting steel panels. The instruments and auxiliary apparatus were previously developed for other applications in the electrical field and have been adapted to the solution of train performance problems with relatively few changes in basic design. Two phases of a conventional 110-volt 60-cycle 3-phase distribution system supply through 3-ampere fuses all the electric energy required by the machine. Calculations are not affected by fluctuations in supply voltage. After the auxiliary circuit has been calibrated for the acceleration-speed curve which applies to the particular train, calculation of performance is automatic except for changes in grade and changes in type of motion for which manual adjustments are made as the calculation is progressed. Results are produced on strip charts which show continuous curves of (1) acceleration at any time, (2) speed at any time, and (3) speed at any distance. Time in 5-minute intervals is marked on the speed-distance chart.

In this calculator acceleration is expressed in terms of voltage, which is measured and integrated with respect to time to control a second voltage proportional to speed. The second voltage is similarly measured and integrated with respect to time to operate a chart-drive motor. As motor revolutions represent speed integrated with respect to time, the chart is advanced at a rate proportional to distance traversed.

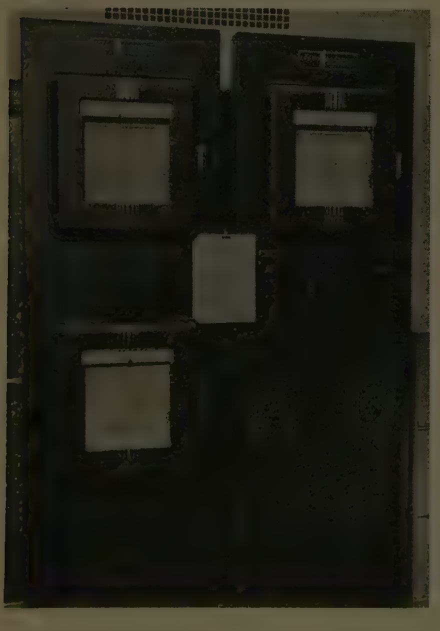

Figure 1. Front view of the new train performance calculator

General arrangement of instruments and control apparatus is shown in Figure 1. In accordance with the primary quantity measured, the top instrument on the left panel is designated the Speed recorder; the lower instrument, the Distance recorder. The instrument on the right panel is the Acceleration recorder. Charts in the upper instruments are advanced by synchronous motors. The chart in the Distance meter, on which compensated grades, speed restrictions, and braking lines are previously plotted or indicated, is advanced by the motor controlled by the speed-voltage integrator.

The four rows of dials shown on the lower portion of the right panel represent rheostats connected between positioned taps on a slide wire in the Speed recorder. These rheostats are adjusted prior to the calculation to produce along the slide wire a voltage gradient conforming to shape and proportions of the net acceleration-speed curve for the selected train. The dials immediately above represent rheostats which simplify the calibration procedure and provide features for the net acceleration-speed curve.

Below the Acceleration recorder, from right to left, are a Power on-off switch, a Grade and Braking rheostat, and an Operations switch. The acceleration circuit is supplied with proper voltages for grade or braking by adjustment of the rheostat so named, and can be arranged for three types of motion—acceleration, fixed speed, or braking—by adjusting the Operations switch. Progress of the speed curve on the prepared distance chart determines the nature and extent of each adjustment.

Calculations have been compared with those performed by the step-by-step method and with actual train performance. No evidence of machine inaccuracy has been found to date. Maintenance and dependability of measuring and integrating mechanisms are consistent with those of similar devices used for other purposes in the electrical industry. The ease and consistency with which these normally cumbersome calculations have been handled with this machine have encouraged extensive preliminary investigations and provided convincing arguments on proper assignment and rating of new motive power for many railroad services.

Digest of paper 51-108, "A New Train Performance Calculator," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Giovanni Giorgi
(1871–1950)

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The rare combination of a theoretician and a practical engineer was found in Giovanni Giorgi. His theory of alternating sinusoidal currents and their representation by means of vector diagrams is fundamental to the science of engineering. At the same time he planned and organized many civic engineering projects for the benefit of his people.

G IOVANNI GIORGI, who first proposed the mks (meter-kilogram-second) system of units, died suddenly in Castiglioncello, Italy, on August 19, 1950. ofessor Giorgi's contributions to electrical engineering d science in general amount to more than 300 papers. ese were published from 1894 to 1950,[1] and through them can follow the develop- nt of electrical engineering m its early struggles to its sent achievements.

Giovanni Giorgi was born in cca, Italy, on November 27, 71, and was graduated with nors from the University of me in 1893. He began his ofessional career as a practic- engineer, and from 1895 to 05 he designed and built eral hydroelectric plants, nsmission lines, distribution tems, industrial installations, ctrical tramways, and rail- ys. At the same time he s writing technical papers problems of electrical engi- ering, electricity and mag- tism, theoretical physics, trology, and rational me- anics.

Giovanni Giorgi

He soon was concerned with theory of alternating sinusoidal currents and of their presentation by means of vector diagrams. A review icle of his work on the subject, published in 1903, is great importance even today. Other works are con- ned with the basic principles of electricity and with fundamental concepts of mass, time, and motion.

These works introduced Giorgi's work on electrical trology. The system of units proposed by him in 1901 known universally. It was adopted officially by the ernational Electrotechnical Commission (IEC) in 1935 h the following resolution: "That the system with four damental units proposed by Professor Giorgi be adopted, subject to the fourth fundamental unit being universally selected."

At the same meeting of the IEC, it was decided unanimously that the system with four fundamental units should be named the Giorgi system. At the 1938 meeting it was decided to use as the fourth unit, the connecting link between the electrical and mechanical units, the permeability of free space. The question of rationalization was left open by the commission; although Giorgi, like Heaviside, was decidedly in favor of rationalization. Consequently, the commission resolved that the fourth unit would have "the value $\mu_0 = 10^{-7}$ in the unrationalized system or $\mu_0 = 4\pi \times 10^{-7}$ in the rationalized system."

Less well known is the fact that Giorgi had associated the new systems of units with a new exposition of the electrical theories. This exposition is not based on the classical, and seldom performed, experiments (like the demonstration of Coulomb's law) of the old treatises of physics, but instead on concrete magnitudes—the volt, ampere, and ohm—which lead directly to the most important applications of the theory. Death interrupted Professor Giorgi while he was working on two new textbooks on electricity and magnetism, one elementary and one advanced.

Another important work of Professor Giorgi, published in 1905, was concerned with a "Unified Method for the Study and the Computation of Electrical Machinery." At that early date, it was very important to show how the same basic concepts applied to the various electric machines, which were regarded then as entirely different from each other.

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In the more purely mathematical field, Giorgi published in 1903–05 two very remarkable papers, which were the first to give a rigorous form to the operational calculus. Giorgi was the first to apply the Laplace transform to the symbolic or operational method, showing the connection between this powerful and rigorous mathematical tool and the Heaviside approach. It should be recalled that Heaviside introduced the Laplace transform only in the third volume of his "Electromagnetic Theory" which was published in 1912.[2] Unfortunately, Giorgi's work was published in a relatively unknown magazine, in Italian, and was then too difficult for many electrical engineers. Thus, later contributions (as Carson's) overshadowed Giorgi's original contribution. A subsequent work by Giorgi on this subject is the communication to the International Congress of Mathematics in Toronto (1924) entitled "The Functional Dependence of Physical Variables" in which the problem is considered in its generality.

Other papers of Giorgi are concerned with higher mathematics, physical mathematics, and rational mechanics. He studied vector fields, the propagation of waves in mediums with selective absorption, the deformation of space, problems of relativity, functions of complex variables, and many others. His "Summary of the History of Mathematics" earned a well-deserved fame in Italy and abroad.

Giovanni Giorgi, after his private engineering work, took civic assignments and became Director of the Public Works Department of the City of Rome. He planned and organized the Municipal Electrical Company, the electric tramways of the city, the city refrigerator system, and worked on many civic projects in Italian towns.

In 1910 Giorgi became professor at the University of Rome, where he taught mathematics, physics, electrical engineering, and economics. In 1934 he became professor at the Institute of Higher Mathematics in Rome. In 1947, although 76 years old, he was sent by the Italian Government as head of a delegation for the study of long-distance telephone communication in the United States. He represented the Italian Government at the bicentennial celebration of Princeton University. He was for many years a member of the IEC and of many Italian and foreign institutions.

Giorgi's personality was kind, simple, loving, and extremely lucid. All his pupils recall his clear mind, his tremendous culture, and his unfailing kindness and patience. He spoke and wrote in Italian, French, English, and German. His style was elegant, simple, and crystal-clear, devoid entirely of that heaviness, even in the most involved subjects, which often is found today in technical papers.

In the present age, wherein most individuals are led to ever-narrowing specializations, the mind of Giorgi, who excelled in so many fields, appears almost as that of a universal genius. In a certain manner, allowing for the difference of the times, he may be compared to Galileo Galilei. Keeping the comparison to modern times, he may stand next to Steinmetz for contributions to modern electrical engineering. To him, electrical science owes a great deal.

No words in memory of Giovanni Giorgi seem more fitting than those which he himself spoke in memory of a dear friend and colleague, the physicist O. M. Corbino: "What emptiness after his disappearance! And yet our soul is consoled by the thought that his works continue and perpetuate his spirit and his tradition. Honor to his memory."

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2. Electromagnetic Theory (book), **Oliver Heaviside.** The Electrician Publishing Company, London, England, 1894, 1899, and 1912; 3 volumes. Reprinted, Benn Brothers, London, England, 1922.

Water Wheel Generator under Construction for Seattle, Wash.

This 66,700-kva water wheel generator soon will be producing electric power for the city of Seattle, Wash., in the rapidly growing Pacific Northwest. It is being constructed at the East Pittsburgh, Pa., plant of the Westinghouse Electric Corporation. It will be installed in the Gorge power house which is located on the Skagit River above Seattle.

When completed, the water wheel generator will weigh 580 tons; it will stand 21 feet high and will measure more than 36 feet in diameter. The rotor alone will weigh 287 tons; it is designed to turn at a speed of 164 rpm. The two workmen shown are using a pin gauge to check the stator for roundness preparatory to mounting the end bracket.

Some Experiments With Peltier Effect

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IT DOES NOT seem quite logical to an electrical engineer that, when a direct current is passed through a soldered connection between two metals, this junction hould cool off rather than heat up, in spite of the fact that he junction has an appreciable resistance.

This Peltier effect is defined as the effect which gives rise o an absorption or liberation of heat when a current flows across the junction of two unlike metals. Heat is absorbed when the current flows in the same direction as the current it the hot junction in a thermoelectric couple. Thus it may be said to be another aspect of thermoelectric effect, and its magnitude is directly proportional to the so-called thermoelectric power of the combination of metals used, as well as he current through the junction.

Over the past 25 years there has been little of an engineering nature published about the Peltier effect. Some selected references are listed at the end of this article. During and since the war, research work under government sponsorship has been carried on looking toward a practical thermoelectric power generator. Such a generator is needed in some military operations where the noise of a gasoline-driven unit is highly objectionable and batteries are impractical. Most of this work has been on new materials having usable high values of thermoelectric power.

The Peltier effect has long been neglected by electrical engineers. Lately, however, experiments have been made on new alloys to determine the practicability of using the Peltier effect in a thermoelectric power generator.

In general, the fundamental requirements for Peltier couples are the same as for the elements of a thermoelectric generator. These are

1. High contrasting thermoelectric power.
2. Low heat conductivity.
3. High electric conductivity.

The Wiedemann-Franz relation ties factors 2 and 3 together. This "law" states that the product of the coefficients of thermal conductivity and electrical resistance is a constant for any given material. There are some known deviations, but unfortunately they are all in the wrong direction. In other words, no metal or alloy is known which has a lower value (more favorable) for this relation. The various basic design features for a thermoelectric generator design have been pretty well worked out.[1]

The useful net Peltier cooling effect is much less than the total heat abstraction caused by heat resulting from the following factors:

1. The I^2R heating at the joint where the cooling effect takes place.
2. The I^2R heating in the body of the material. This heat flows toward the cool junction.
3. The heat which reaches the cool junction from the surrounding medium.
4. The Peltier heat generated at the hot junction and conducted through the material to the cool junction.

These are listed in order of importance for most Peltier cooling arrangements. These factors in total are usually almost as large as the cooling effect so that the conditions must be very favorable in order to produce a net amount of useful cooling. It will be noted that two of the four factors, and usually the two largest ones, depend upon the square of the current. As the total Peltier cooling is proportional to the first power of the current, there is for any given couple an optimum current to obtain maximum useful cooling.

So far no one has found satisfactory or ingenious ways of greatly enhancing useful Peltier effect by variations in mechanical design. A few ideas have been helpful. One of these is to use lòng rods of materials so that little of the Peltier heat generated at the hot junctions travels to the cool junction. This, of course, lowers the over-all efficiency of the device but does result in a maximum temperature drop at the cool junction. Theoretically the cross sections of materials used should be directly proportional to their specific resistance.

A common fallacy, when one first considers Peltier cooling, is to assume that because a given current creates a temperature difference between the two junctions, if the hot junction is cooled down and thus prevented from rising much above ambient, the cold junction will further drop in temperature by a nearly like amount. This does not occur, however, if factor 4 is minimized by a reasonably long length of couple element.

As a matter of fact, both theory and experiment indicate that if one of the hot ends is cooled there is actually a slight warming up of the cold junction. This is due to Thomson effect. Thomson effect is the phenomenon of the appearance or disappearance of heat in a portion of a conductor when an electric current flows between a cold and a hot part of that conductor. Whether this heat absorption occurs at the cooler or hotter portions depends on the Thomson effect coefficient which, as in the case of thermoelectric effect, may be positive or negative and varies widely with different materials. It is a second-order effect, however, and experiments indicate that it is just detectable without refined equipment and measurements.

What is really needed, for a practical design, is an ar-

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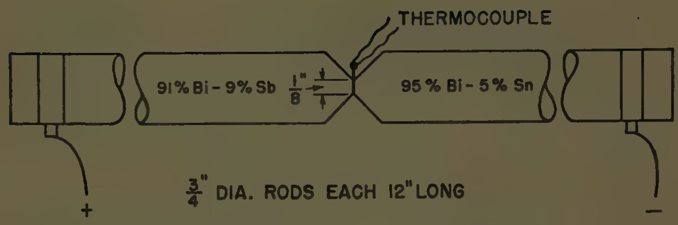

Figure 1. Schematic sketch of an experimental Peltier couple arrangement

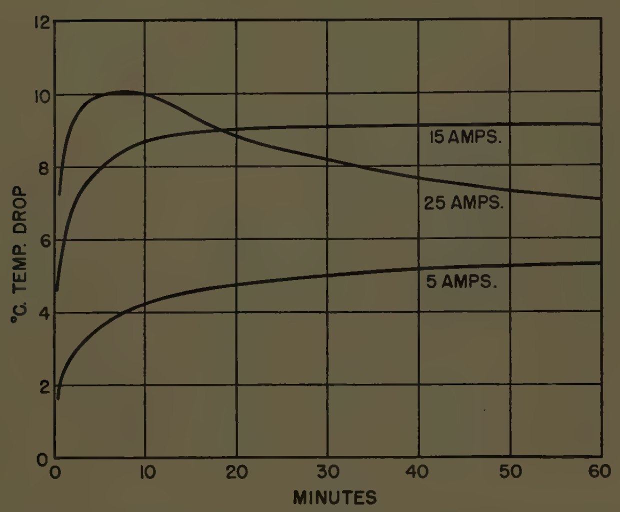

Figure 2. Cooling curve with time, for three values of junction current

rangement by which the Peltier couples may be connected in series thermally as well as electrically. In other words, if a certain Peltier couple lowers the temperature of a small piece of metal by five degrees, it would be highly desirable to have a practical arrangement by which the five degrees' drop from another couple or series of couples can be used to lower the ultimate temperature to something approaching ten degrees. The Peltier effect efficiency is so extremely low that any known series arrangement thermally appears to be prohibitively large and wasteful.

In the literature on thermoelectric generators, calculated efficiencies as high as five to ten per cent are mentioned. However, an actual group of couples assembled in the form of a generator was reported as showing, on test, an over-all efficiency of under one per cent. The same thing is probably true of any known form of practical Peltier cooling device.

Handbooks and other tables of physical constants show very high contrasting values of thermoelectric power for germanium and silicon. However, these two elements, as well as some other semiconductors, have entirely too high an electrical resistance to be used for satisfactory Peltier elements. From the practical aspect, several of the materials with very high thermoelectric power that have been developed, in addition to having a high electrical resistance, are either extremely brittle or are very difficult to solder, weld, or otherwise join together to make satisfactory low-resistance junctions. A low resistance of the "cool" junction is of great practical importance because the heating at this surface, which directly offsets the Peltier cooling at the same surface, is proportional to the square of the current.

For the experiments, a pair of rods 3/4 inch in diameter and 12 inches long were cast; one was made up from 91 per cent bismuth and 9 per cent antimony, the other from 95 per cent bismuth and 5 per cent tin. This choice of alloys represents a compromise between high contrasting thermoelectric power and the requirements of electrical and heat resistivity. These materials also are suitable for soldering to form a low-resistance joint. The rods were tapered down to about a 1/8-inch diameter for the "cool" junction.

Between these two ends was soldered a bit of 30-mil sheet copper 3/16 inch by 3/8 inch, and to this the thermocouple was attached. This arrangement is shown in Figure 1. For the tests the cool junction and about two inches of adjacent length of each rod were wrapped loosely with several layers of paper batting to eliminate effects of variable air currents. The optimum current was found to be about 15 amperes and the temperature drop about 9 degrees centigrade below ambient. The diminishing cross section of rod area approaching the cool junction appears to be somewhat beneficial in obtaining a maximum temperature drop. However, the net amount of heat removed is no greater, and may well be less.

A typical series of curves of temperature drop for this combination is shown in Figure 2. It will be noted that, as the optimum current is exceeded, the initial drop of temperature at the cold junction is greater, but after a short time the excess I^2R heat in the rods flows to the cold junction so that the final temperature drop is less.

The rapidity of the temperature drop the first few seconds after the circuit is closed is of interest. During the first 15 seconds at optimum current (15 amperes), the rate of temperature drop was at the rate of about 1.2 degrees centigrade per minute per ampere. For the first few seconds, it was as much as 3 degrees centigrade per minute per ampere.

Figure 3, taken from the data of Figure 2, shows the shape of the optimum current curve for the arrangement illustrated in Figure 1.

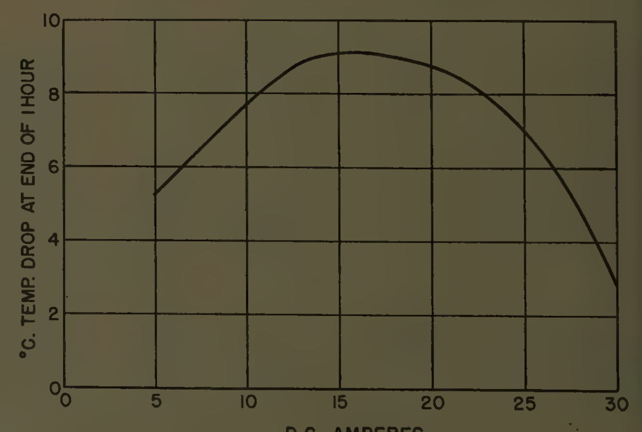

Figure 3. Variation of temperature drop at the end of one hour for different junction currents. The optimum current for this case was about 15 amperes

In Peltier couple tests, it is necessary in most cases to continue one set of conditions for at least an hour (longer if larger masses of materials are used) in order to reach equilibrium temperature conditions.

With present knowledge, a practical Peltier effect cooling device does not seem to be very promising. In order to make it practical, it will be necessary to find new alloys or materials for the couples that have much higher contrasting values of thermoelectric power as well as satisfactory electric and thermal conductivity. Such alloys would probably be difficult to handle and fabricate. If they do become available, there still will remain the problem of a satisfactory design to lower the useful temperature by more than that obtainable in a single Peltier couple.

The best that can be done at the present time is to cool a small bit of metal by not more than 10 degrees centigrade. This amount of temperature drop might be used, for instance, for a very small dew-point determination mirror (for high humidities) or for reference thermocouples to be held slightly below ambient temperature. The useful rate of heat removal per ampere of optimum junction current corresponds to only milliwatts. Until such time as something new is uncovered, the possibility of a household refrigerator based on Peltier effect is unlikely.

There is one encouraging factor. Many able physicists are working to increase our knowledge of the physics of the solid state, particularly in the field of semiconductors. This research may well uncover some new materials, concepts, or ideas that will allow a greatly improved Peltier cooling device to be designed.

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Insulation Tester for the Windings of Large D-C Machine Armatures

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MEMBER AIEE

A new winding insulation tester has been built which extends the application of this type of apparatus to cover low-impedance windings. With this new tester weak insulation on large d-c armatures can be detected, so that design and manufacturing techniques can be improved.

THE QUALITY of the insulation system of electric apparatus is an important factor in the life and performance of that apparatus. To assure the required quality of insulation, adequate and practical means of testing must be provided. These testing methods must meet several requirements. The test-voltage stresses must be applied to the major insulation between the electric circuit and ground and also to the minor insulation between coils and turns. The test voltage applied must simulate service stresses. The test-voltage levels must be sufficiently high to assure that all insulation defects and incipient faults will be discovered. The test must be simple in application and safe. The test equipment must be low in first cost and have reasonably long life.

COMMONLY USED TEST METHODS

BY FAR THE greatest amount of high-potential testing is done at power-supply frequencies at voltage levels determined by experience in field operation. Generally these tests are made on major insulation only by applying voltage to all terminals with the framework grounded. This method of testing does not test coil-to-coil or turn-to-turn insulation. Induced-voltage testing sometimes is used, generally at 120, 420, or 960 cycles, with the applied voltage across the winding under test.[1,2] The higher reactance at these frequencies permits higher applied voltages without overloading. Voltages and currents at these frequencies are not typical of operating conditions so that these tests are not always entirely satisfactory.

Surge testing has been widely adopted for transformers and switchgear. The advent of the Marx circuit and cathode-ray oscillograph has permitted the application of test surges at any peak voltage required, as well as accurate

Full text of paper 51-74, "Winding Insulation Tester for D-C Armatures," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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measurements of applied wave shapes. These tests are made on the single-surge basis, using wave shapes regarded as simulating power-line surges from lightning and other disturbances.

Surge testing of rotating machinery windings using

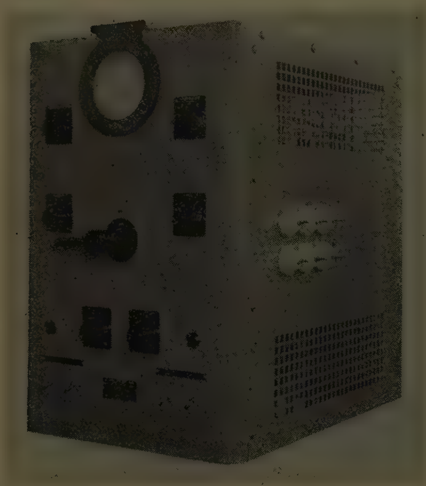

Figure 1. Ten-kv winding insulation tester

repeating-type surge generators at 60 surges per second is now in extensive use on production lines.

REPEATED SURGE TESTING

THE REPEATED-SURGE method of high-potential testing was developed and incorporated in a winding insulation tester for production line use in 1942.[3] Early applications were on 3-phase motors between 1 and 15 horsepower. A short time later a tester was built for larger machines up to 6,000 horsepower with 2,700-volt windings. Still later it was adapted to single-phase motors, and now a large percentage of motors used on refrigerators, washing machines, and others are tested by this method. The wide acceptance of the winding insulation tester of Figure 1 is

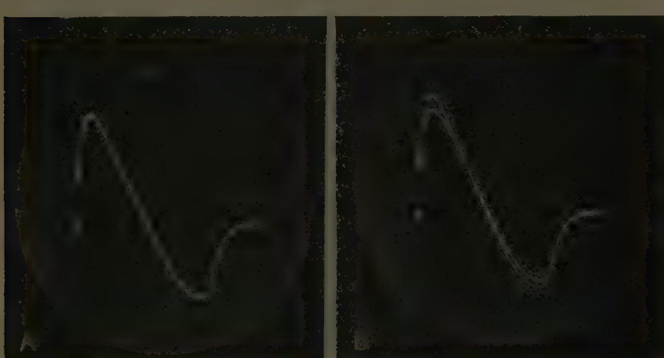

Figure 2. Test waves for single-phase motors. (A) good windings, (B) several short-circuited turns in one coil

based on the economy and convenience of repeated surge testing in providing the required insulation stresses from conductor to ground, between coils, and between turns. Figure 2 shows typical test waves on single-phase motors. Figure 2*A* was obtained with a good winding; *B* was obtained with several short-circuited turns in one coil durin the test.

With this tester all insulation faults are detected and located, providing designers with information necessary for changes in design and manufacturing methods, which results in reducing production line rejections to well under one per cent.

WINDING INSULATION TESTER FOR D-C ARMATURES

THE SUCCESS OF repeated surge testing on stators immediately suggested a possible application to d-c armatures where similar problems of turn stresses due to surges must be met. Here the problem becomes more difficult because of the low impedance of the armatures to be tested and the correspondingly greater surge current required for a given turn-to-turn surge voltage.

This problem first came up during the last war when the United States Army required a number of special d-c trac-

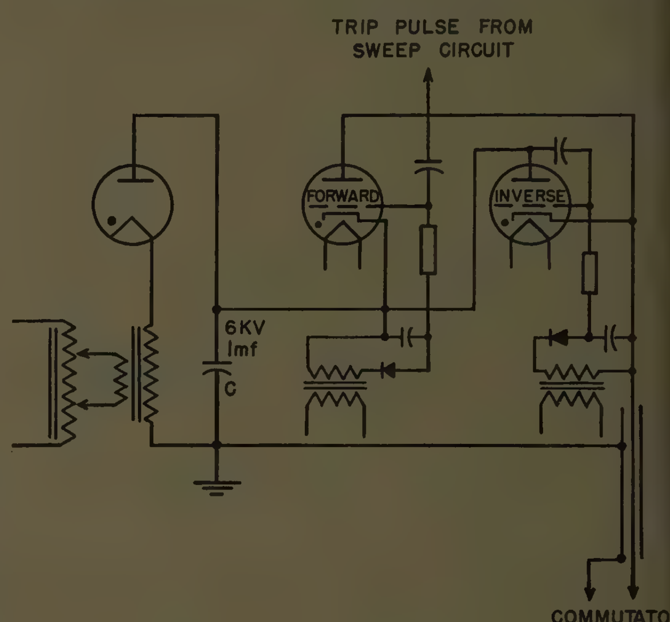

Figure 3. Main circuits of 10-kv winding insulation teste

tion motors. The design of these motors was such tha stringent insulation space limitations were imposed. Because of this, and also as a result of the rigid service specifications, it was necessary to make a severe turn-to-turn insulation test on the armatures.

These armatures were lap-wound and had the usua equalizer connections. The resistance between adjac commutator segments was less than 0.001 oh previous experience with the type of insulatio armature, it was decided that a surge test giving 500 volt peak bar-to-bar would show up substandard insulation bu would not damage good insulation. Tests also indicate that at 500 volts' peak the surge current would be in exces of 300 amperes. This power requirement was greater tha could be obtained from any existing surge test equipmen To meet these power requirements a new surge tester wa designed and built.

The main circuits of this tester are shown in Figure

The surge generator capacitance C of one microfarad was charged in one half-cycle and discharged on the next half-cycle. The discharge was through a pair of thyratrons connected back to back to permit oscillatory and complete discharge of the surge generator.

The surges were led to the motor under test through coaxial cables to minimize reactance drop. A well-insulated contact mechanism held by the operator applied the surges to adjacent commutator bars. A separate pair of contacts picked off coil potential and another coaxial cable took it back to the oscilloscope for observation and measurement.

The armatures were checked at certain stages of manufacture when defects could be corrected at minimum expense. The performance of this special winding insulation tester on this lot of motors proved the value of surge testing for incipient fault detection and insulation system evaluation.

The use of this tester was continued after the war to test armatures of various sizes and types of windings. From this background of experience it was decided in 1949 to extend the program of surge testing. This program included armatures of very low impedance. Tests showed that to provide bar-to-bar test potentials of 500 volts' peak, crest currents of several thousand amperes would be required. The use of thyratrons to obtain these current values was impractical so a new surge tester was designed and built using small ignitrons which are capable of supplying the current required of the tester.

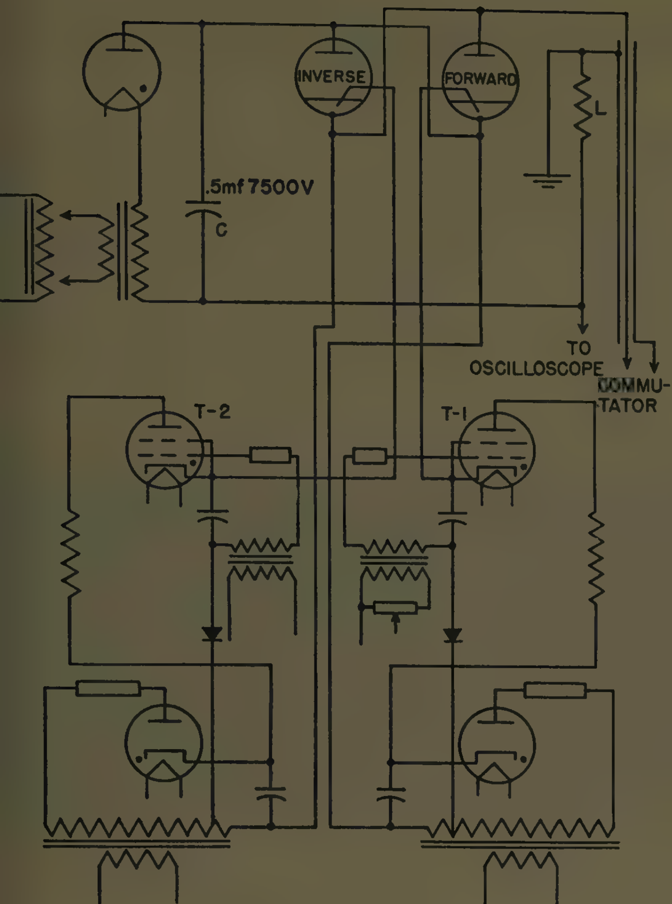

Figure 4. High-current winding insulation tester, final design

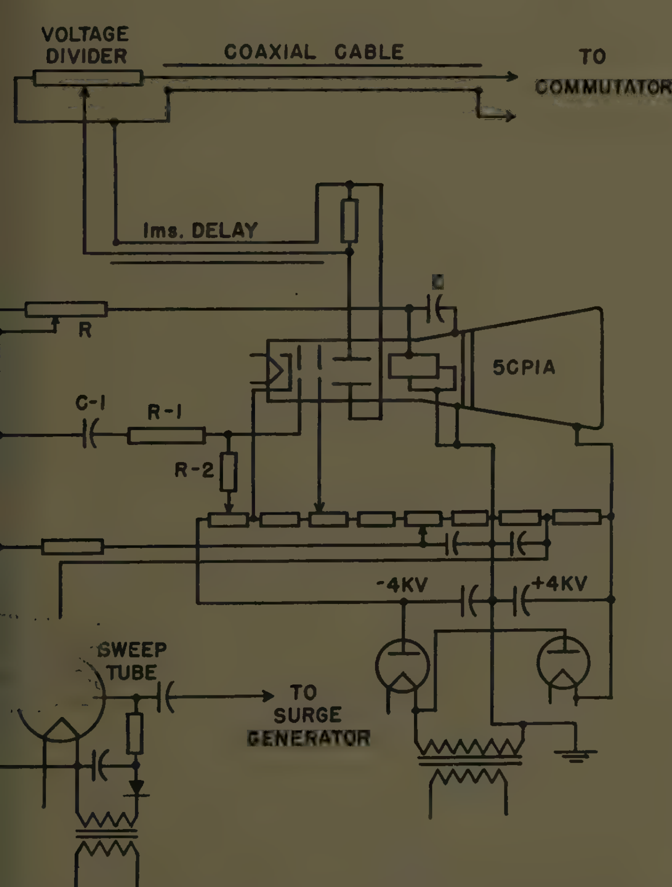

Figure 5. Oscilloscope circuits for the new winding insulation tester

Figure 6. Contact mechanism for applying tester output to commutator

DESCRIPTION OF THE NEW TESTER

The surge generator of the new high-current winding insulation tester as finally developed around the ignitrons is shown in Figure 4. The capacitor C is charged on one half-cycle and discharged on the next half-cycle of opposite polarity. The discharge tends to be oscillatory, so a second ignitron to carry the inverse current is provided. Each ignitron has its own firing circuit which sends a current pulse of 500 microseconds' duration through the ignitor. As the time required to fire the ignitor varies between 20 and 40 microseconds, and as the first half-cycle of the surge may be shorter, it is necessary to fire the inverse tube first. This insures that the inverse tube will always be ready when the inverse surge current comes along.

The inverse firing circuit thyratron *T-2* grid has a negative bias of about 30 volts which is modulated by about 250

volts at 60 cycles so that firing occurs very soon after the zero of the charging half-cycle. The forward firing circuit thyratron *T-1* is controlled in the same way, but has its grid bias modulated by a lower 60-cycle voltage so that firing is delayed a little longer.

The positive side of the surge generator is connected to ground through a small coil *L* of several turns. The positive drop across this coil is used for firing the sweep circuit of the oscilloscope, thereby giving a perfectly steady picture on the oscilloscope screen in spite of the variations of ignitron firing point.

The oscilloscope circuits are shown in Figure 5. A 5-inch fast-writing oscilloscope tube with ±4-kv acceleration, or a total of eight kv, is used to give enough intensity for convenient observation. The time axis is produced by the discharge of a small thyratron into a resistance-capacitance circuit. The thyratron also drives the cathode-ray tube grid to establish the beam through a coupling capacitor *C-1* and resistance voltage divider *R-1*, *R-2*. Power for the sweep tube is supplied by taps in the main 8-kv power-supply bleeder.

To avoid including the contact drop of the main contacts, the surge voltage to be measured is picked up by separate contacts and conducted to the oscilloscope deflection circuit through a coaxial cable. The voltage divider is made up of noninductive resistors on a tap switch. The output of the divider is passed through a 1-microsecond delay cable to the deflection plates of the cathode-ray-tube. This delay makes up for the time lost in initiating the time axis circuit.

Several other elements which were omitted from the diagram for simplicity are a deflection selector switch, a d-c calibration supply, and a 500-kc damped-wave timing wave oscillator.

The contact mechanism for applying the tester output to a commutator is shown in use in Figure 6. It consists of a well-insulated body with two handles in which there are interlock switches. The operator is safeguarded in this way as he must press both handles to complete the surge generator primary circuit. The contacts are adjustable for commutators having bars of various widths, and it may be used on commutators up to 31 inches in diameter. For commutators of larger diameters another mechanism of similar design will be required.

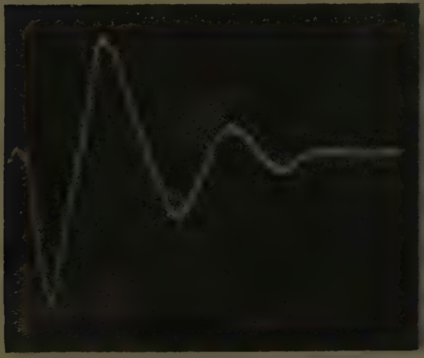

Figure 7. Oscillograph of voltage wave between adjacent bars of very-low-impedance armature

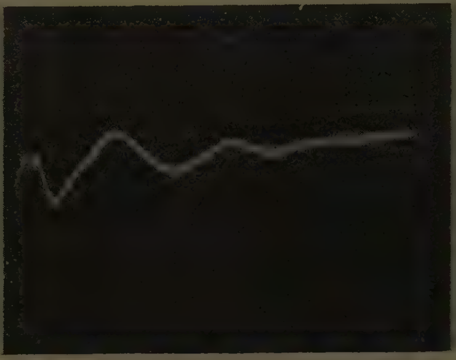

Figure 8. Oscillograph of voltage wave with deliberate insulation defect in armature circuit

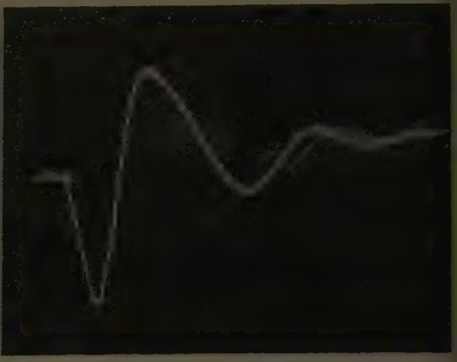

Figure 9. Oscillograph of voltage wave without insulation defect, on medium-impedance armature

APPLICATION PERFORMANCE

The surge generator capacitance of 0.5 microfarad can be charged to a maximum of 7.5 kv. The generator is capable of applying potentials up to 1,000 volts peak between adjacent segments of any d-c armature now in production. An oscillograph record of voltage between adjacent bars of a very low impedance armature is shown in Figure 7. This voltage wave is of highly damped nature at a frequency of approximately 160 kc. The voltage amplitude of 500 volts between bars is only a portion of the total surge-generator voltage, the remainder being lost in the stray inductance of the leads. This wave shape is typical of an armature circuit with no insulation defects.

The wave shape obtained when an insulation defect is present in the armature circuit is shown in Figure 8. This particular defect was a short circuit between bars in a coil 120 degrees or one equalizer space from the point of surge application.

A typical wave shape on a medium-impedance armature without insulation defects is shown in Figure 9. The increased inductance of this armature reduces the oscillation frequency to approximately 130 kc. The general wave shape, however, remains quite typical of those for large armatures.

This tester may also be applied to higher impedance loads such as series field coils and a-c stator coils. The a-c stator coils may be tested after installation to detect damage due to installation. Up to 7,500 volts is available for such work, which is probably high enough for detecting damage or defective insulation even though a first-class coil may take two or three times as much to break it down.

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Humidity and Time Effects on Spark-Over

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THIS INVESTIGATION was suggested when it was observed that gaps in high direct-voltage equipment exhibited erratic and rather low breakdown strength during moderately high humidity conditions. Electrode edges were slightly rough in some of the gaps.

A negative coefficient of breakdown or spark-over voltage with humidity variation as indicated is somewhat surprising at first because with 60-cycle and impulse voltages the standard sphere gaps are virtually unaffected by humidity, while rod gaps with sharp edges have a positive humidity coefficient. (See the applicable AIEE Standard.[1]) In view of the apparent lack of published information on the effects of humidity and time of application of direct voltages on the breakdown strength of gaps, it was decided to conduct a systematic investigation on the relative effects of these factors.

Tests were performed on two electrode configurations: 12.5-centimeter diameter spheres, and standard one-half inch square rods with square edges. The advantages of this selection are: (1) it allows comparison with present accepted 60-cycle data, (2) it provides opportunity to compare results for gaps with and without corona formation before spark-over, and (3) it brackets the electrode configurations in commercial direct-voltage equipment.

The source of direct voltage was a 100-kv rectifier unit with capacitance output and grounded center tap. Voltages were measured with an electrostatic voltmeter connected across the center section of a corona-free wire-wound divider of 40 megohms total resistance. The ripple amplitude was found to be less than 0.25 per cent.

Four spacings were selected for each gap so that the spark-over values were approximately 30, 50, 70, and 90 kv. Two types of data were taken for the sphere gap and the rod gap: initial spark-over voltage and voltage-time characteristics. The latter were obtained by setting the voltage at successively lower values and recording the time to spark-over. The highest voltage not causing spark-over in three 90-second runs was designated as the critical withstand value. This time was chosen because it was demonstrated that spark-overs after 90 seconds were very improbable. Data were taken over a 3-month period during which humidities from 0.25- to 0.73-inch mercury-vapor pressure were encountered.

For the sphere gap, the initial direct spark-over voltages were found to be practically independent of humidity, although there is a suggestion of a slight positive humidity coefficient. Short-time (two to five seconds) spark-over voltages obtained at seven different humidities, when averaged for each gap and compared with 60-cycle values in the Standard,[1] show a mean deviation in results of 1.1 per cent. This is within the absolute accuracy of the measurements, considering all factors.

On applying to the sphere gaps steady voltages two per cent (in some cases three per cent) less than the short-time spark-over values, random spark-overs were observed at times averaging about 30 seconds. A suggested explanation for this is that cosmic rays are triggering the gap. In any event, the critical direct withstand voltages for the sphere gap are not much less than the short-time spark-over values, and no dependence on humidity was observed.

In order to minimize scattering of initial direct spark-over voltages for the rod gap, it was necessary to raise the applied voltage very rapidly. Spark-over values so obtained show general agreement with accepted 60-cycle values, although the observed positive humidity coefficients for these relatively short gaps are somewhat greater than for 60-cycle spark-over. Dual spark-over voltages much less than the 60-cycle values were encountered intermittently if brush formation was permitted to develop at rather critical voltages.

In addition, on applying sustained direct voltages to the rod gaps at values successively lower than the initial spark-over value, spark-overs were observed at random times that show a trend to longer average times at the lower voltages. Plots of critical withstand voltages versus humidity indicate a small negative humidity coefficient for the four gaps investigated, but the scattering of results is such that the uncertainty in the coefficient is considerable. The extrapolations of the curves of initial spark-over voltages and of long-time spark-over voltages versus humidity intersect at zero humidity within the accuracy of the data.

Further analysis indicates that for dry air the rod-gap spark-over voltage probably does not depend greatly on the time of voltage application for times greater than 0.1 second. When water vapor is present in the air, the rod-gap unidirectional spark-over voltage is greater than the dry-air value for all times of voltage application up to a few seconds, but it decreases to a level near the probable dry-air value at longer times. The latter result may be caused by: (1) gradual coalescence of water droplets in the glow discharge that exists at sharp electrode edges at subinitial spark-over voltage; (2) migration of these high-permittivity droplets to regions of the gap where the field intensity is relatively high; and (3) disruption of the droplets by the field, leading to a chain of water particles and consequent spark-over. Further investigation of these phenomena is required.

Digest of paper **51-173**, "Dependence of Direct Spark-Over Voltage of Gaps on Humidity and Time," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Technical Program Committee for presentation at the AIEE Great Lakes District Meeting, Madison, Wis., May 17–19, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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Switching High-Voltage Shunt Capacitor Banks

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ONE OF THE first 34.5-kv capacitor banks in this country was installed recently on the Indianapolis Power and Light Company system. This capacitor bank, totaling 7,290 kva, was part of a system program of adding reactive generation close to reactive load in the most practical and economical manner. See Figures 1 and 2.

As there was very little test data available on the performance of circuit breakers in switching large capacitor banks at 34.5 kv, oscillographic records were made when the capacitor bank was placed in service. The overvoltages produced on the 34.5-kv system when the capacitor bank was switched were usually less than 2.0 times the normal line-to-ground crest value but did reach a value of 2.4 times normal on one test. These overvoltages are within the range produced in the interruption of reactive currents.

Although these overvoltages caused no damage to equipment on the 34.5-kv system, they did cause lightning-arrester failures on two 4-kv feeder circuits off the bus of a nearby substation supplied by the same 34.5-kv system. As no lightning arresters failed on the 4-kv feeders out of the substation where the capacitor bank was located, tests were made to determine the reason for lightning-arrester failures on the other 4-kv feeders.

Investigation showed that a voltage surge at one voltage level, such as produced by capacitor switching, can set up relatively greater voltage oscillations at another voltage level under conditions of coupling and circuit constants.

The 34.5-kv oil circuit breaker used to switch the capacitor bank was modified by auxiliary oil pistons after high-power laboratory tests indicated this design change to be most effective in reducing both the magnitude and number of overvoltages produced during the interruption of capacitor currents. Two auxiliary oil pistons were added to each De-ion grid in the circuit breaker. These pistons were charged with oil on the closing stroke of the moving contact. At the same time, a driving spring in each piston was compressed. On the opening stroke of the moving contact the auxiliary pistons, driven by the compressed springs, forced oil under pressure into the arc space to drive out the gases produced by arcing. The ends of the moving contacts were reduced in cross section so that the arc position was closely determined and the oil passages formed in the upper section of the grid could be brought close to the arc. As a result, only a small quantity of oil needed to be pumped.

After testing the modified interrupters under short-circuit conditions, a set was made to this design and installed on the circuit breaker to switch the 34.5-kv capacitor bank.

A final series of 22 tests was made with these interrupters switching the 34.5-kv capacitor bank. There was no damage to equipment; only one restrike and one reignition occurred. The maximum voltages produced were 2.1 times normal on the 34.5-kv bus at the capacitor bank location and 1.9 times normal on the 4-kv bus of the nearby substation.

After these tests the capacitor bank was put into service, being switched on and off each day. During ten months of operation no damage to system or equipment occurred.

Figure 2. 7,290-kva capacitor bank installation

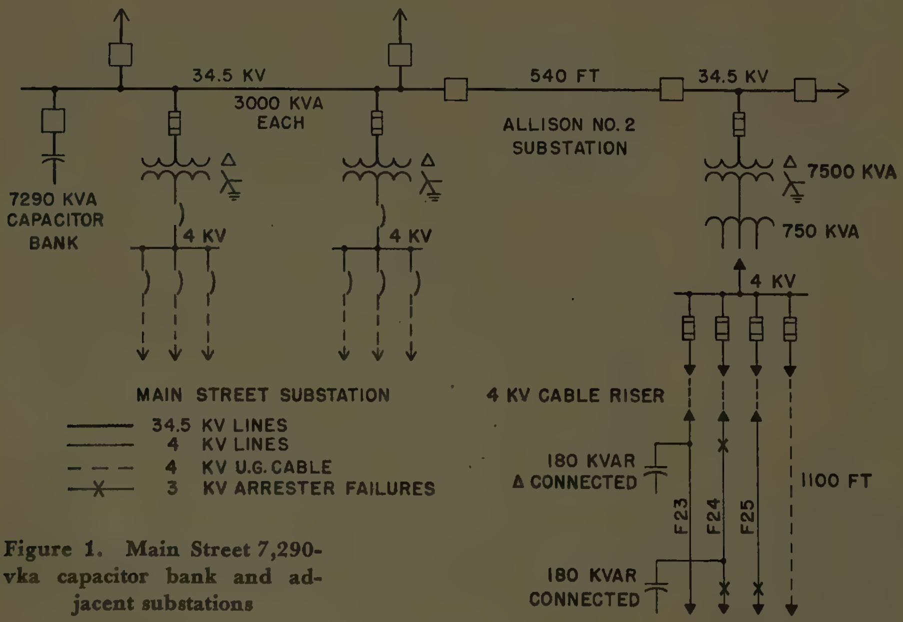

Figure 1. Main Street 7,290-kva capacitor bank and adjacent substations

Digest of paper 51-18, "Switching High-Voltage Shunt Capacitor Banks," recommended by the AIEE Committees on Switchgear and Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

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A Compensated Thermal Anemometer and Flowmeter

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A THERMAL anemometer with unusual sensitivity, accuracy, and ruggedness has been developed for laboratory and industrial use. It operates from a heated noble metal thermopile which is placed in the airstream whose velocity is to be measured. The anemometer is practically independent of temperature over a considerable range since both the hot and cold junctions are exposed to the airstream and are equally affected by ambient temperature. Radiation effects tend to cancel in the same manner. Thermopile probes of suitably chosen materials have been used satisfactorily at temperatures as low as −65 degrees Fahrenheit and to above 300 degrees Fahrenheit. The outstanding feature of this anemometer is that the transient thermal voltage produced in the heated thermopile by sudden changes in ambient temperature is counterbalanced by the equal and opposite transient thermal voltage of an unheated thermopile located in the probe and exposed to the airstream whose velocity is being measured. This arrangement compensates completely for rate of change of temperature.

The unique circuit of this thermal anemometer permits construction of a thermopile to include any number of thermocouples necessary to insure sufficient electrical output with a minimum of temperature difference maintained between thermojunctions. This temperature is limited to minimize the induced air circulation effect of the wire temperature on the very low velocity calibration.

The thermopile consists of a series of thermojunctions with alternate junctions fastened to strong mounting studs which have high thermal conductivity. The thermopile is heated by an alternating current but flow of air tends to reduce the temperature of the thermopile wire. A thermal difference results between successive junctions which induces a d-c thermal voltage proportional to the temperature difference and bearing a direct relationship to the air velocity in accordance with King's equations.

The velocity-measuring range of this type of instrument can be varied through wide limits by changing the relative distances between the hot and cold junctions of the thermopile, and by varying the amount of heating current applied and the aerodynamic cooling. Practically any degree of sensitivity can be obtained. Thermopile anemometers of the type described have been used for indicating and recording flow velocities as low as five feet per minute and as high as 400 miles per hour. Velocity calibrations on strip chart recorders are shown in Figure 1 for anemometers which were designed specifically for high sensitivities at opposite ends of the velocity range.

An inexpensive 2-thermocouple instrument designed especially for use in air-conditioning, heating, and ventilation fields is small enough to be held in the palm of the hand while measuring velocities. This same unit permits incorporation of the thermopile element in a pipe or duct to measure the rate of flow of gas through the pipe.

Among other problems to which the thermopile anemometers have been successfully applied are: measurement of ventilation between layers of clothing; studies of plant ventilation; and meteorological measurement of wind velocity. Pickup probes have been designed specifically for nondirectionality, and in other applications probes have been designed for high directionality for application to detection and measurement of flow angle.

Due to the high response of the thermocouples employed, small and rapid air fluctuations have been measured by the use of high-frequency indicators and recorders. In other applications averaging is achieved by the use of well-damped long-period indicators and recorders.

Digest of paper 51-149, "A Compensated Thermal Anemometer and Flowmeter," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Southern District Meeting, Miami Beach, Fla., April 11–13, 1951. Not scheduled for publication in AIEE *Transactions*.

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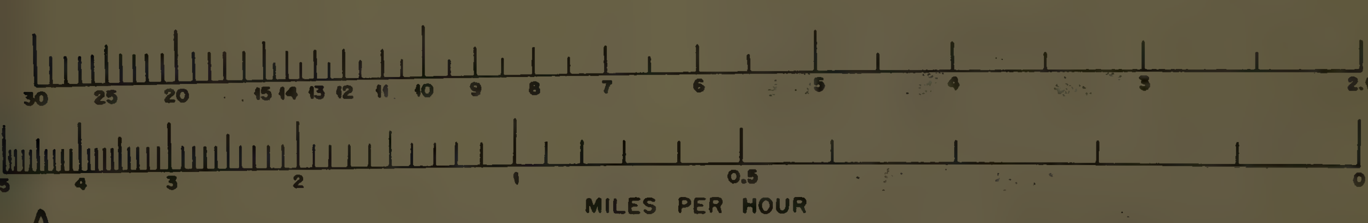

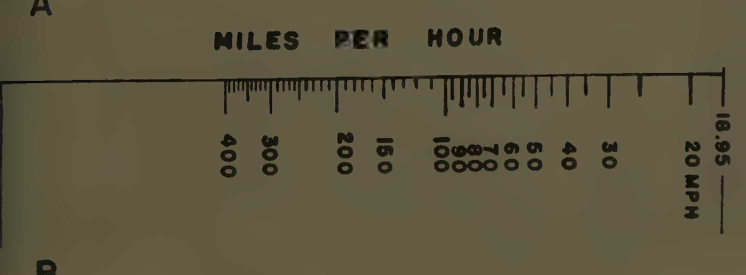

Figure 1. Air-meter calibration on Brown strip char potentiometer

A Two-Range low velocity calibration on a Brown 11-inch strip recorder

B High range velocity calibration on an Esterline-Angus 5-inch strip recorder

A-C Motors for Oil-Well Pumping

M. H. HALDERSON

Studies have been made to determine the most desirable motors to be used for oil-well pumping. From consideration of the type of load, starting requirements, cost, and operating conditions it was found that high-torque motors with 5- to 8-per cent slip will give best service on polyphase lines and 2-value capacitor-type motors will be best on single-phase lines.

MANY TYPES of a-c motors have been used for oil-well pumping. Open wound-rotor motors were used almost exclusively prior to 1930. Since 1930 the electrical characteristics of motors installed for oil-well pumping range from normal torque, normal slip, normal starting current to high torque, 8- to 13-per cent slip. Frame types range from open to explosion-proof. The diversity of types of motors used for oil-well pumping suggests that the various types are equally desirable, but this is not the case. Experience and a more fundamental approach to the evaluation of motors now make it possible for oil producers to select the type of motor that costs the least per horsepower capacity and that has the most desirable characteristics for the conditions encountered in driving pumping units.

Factors that must be considered in selecting motors for oil-well pumping are the type of load, starting requirement, initial cost of motors, and the fact that the motors must operate in the open. Evaluation of available motors with respect to these factors leads to the conclusion that high-torque 5- to 8-per-cent-slip motors in a dripproof or protected frame should be purchased for installations where polyphase electric power is available. Two-valve capacitor-type motors in a dripproof or protected frame are preferred where single-phase power must be used.

Motors with 5- to 8-per cent slip are preferred for driving pumping units because they have the best starting characteristics and because, compared to normal-slip motors, they will carry 35 per cent more load per name-plate rating, will operate with 20 points higher power factor, and will operate with 25 per cent less peak power input. Dripproof or protected frames are preferred because motors built in these frames have the greatest thermal capacity per dollar invested and because experience has shown that these frames provide ample protection.

Figure 1. Electric-motor-driven pumping unit

Load characteristics are such that motors installed on pumping units cannot average an output equal to name-plate rating without being thermally overloaded. Based on tests in the field, the recommended procedure for sizing the two types of motors most frequently used for oil-well pumping is to assume that 5- to 8-per-cent-slip motors can average an output equal to 76 per cent of name-plate rating and that normal slip motors can average an output equal to 56 per cent of name-plate rating.

Motors rated 440 volts have been standard for oil-well pumping. Consideration of Y-connecting 440-volt motors to permit operation at 760 volts is recommended where wells are spaced greater than 660 feet apart and where motors larger than 25 horsepower will be used.

ELECTRICAL CHARACTERISTICS

ELECTRICAL characteristics available for polyphase motors include (1) normal torque, normal slip, normal starting current; (2) normal torque, normal slip, low starting current; (3) high torque, normal slip, low starting current; (4) high torque, 5- to 8-per cent slip; and (5) high torque, 8- to 13-per cent slip. Although catalogue literature does not always so state, 5- to 8-per-cent-slip and 8- to 13-per-cent-slip motors have low starting current.

Selection of the electrical characteristic best suited for driving pumping units is based on the starting requirement, the performance of motors with the various characteristics when applied to the load encountered on pumping units, and the initial cost of motors. Data on the performance of the high torque, 8- to 13-per-cent motors are not available and conclusions regarding 8- to 13-per-cent-slip motors are based on their initial cost and estimates of their performance compared to other types of motors.

STARTING REQUIREMENTS

FIGURE 1 shows a typical electric-motor-driven pumping unit. The majority of such installations are started automatically, and an essential requirement is that motor

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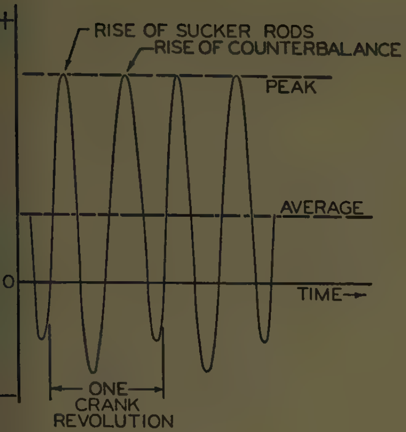

Figure 2. Load imposed on the speed reducer of a properly counter balanced pumping unit

arting torque be great enough to start the pumping unit ithout the assistance of an operator. Measurements of e torque required to start pumping units are not available, ut experience has shown that motor starting torque must e greater than that required for ordinary continuous-ervice applications. Numerous installations have been nade where pumping units could not be started without ocking the beam of the pumping unit. There also have een instances where motors could not start pumping nits even though the motors would have been of sufficient ize to operate the units had starting been possible.

Motors for oil-well pumping should have both high tarting torque and low starting current to insure positive tarting and minimum cost for distribution lines. Starting orque developed by a motor installed on a pumping unit determined by the locked rotor torque of the motor at ated voltage and also by the terminal voltage during the tarting period. Line-voltage drop during starting is more ritical than is sometimes realized because starting torque aries as the square of the voltage and because motors may e as far as a mile from the source of low-voltage power. s often as not, the minimum size of wire required for istribution lines is determined by voltage drop on starting ather than voltage drop on running.

Normal-torque normal-slip low-starting-current motors, vhich have a locked rotor torque of 135 to 160 per cent of ull-load torque, will usually start pumping units providing he motors are sized 50 per cent larger than required to arry the running load without being thermally overloaded nd provided the terminal voltage on starting is not less han 84 per cent of rated. The practice of using normal orque motors is not economical because it results in higher nitial investment for motors and often requires increased nvestment in distribution lines.

High-torque normal-slip low-starting-current motors, vhich have 200 to 250 per cent starting torque and 525 o 700 per cent starting current, will start pumping units n almost all cases provided voltage on starting is not less han 84 per cent of rated voltage.

High-torque 5- to 8-per-cent-slip motors have 275 to 50 per cent starting torque and 500 to 625 per cent starting urrent. These motors have the best starting characteris-ics and frequently will permit the use of smaller wire for ne than that required for high-torque normal-slip motors.

High-torque 8- to 13-per-cent-slip motors have starting characteristics similar to 5- to 8-per-cent-slip motors, but their initial cost is 20 per cent higher than that of 5- to 8-per-cent-slip motors. The purchase of 8- to 13-per-cent-slip motors is not justified, therefore, from the standpoint of starting characteristics.

PUMPING LOAD

DETERMINING the relative merits of the various types of motors for oil-well pumping service is difficult because of the type of load encountered. The pumping load is generally characterized by high peaks and wide and rapid load variation. However, the exact load-versus-time relationship is influenced by many factors and is different for each installation. This makes it impossible to reach general conclusions from a test of one installation.

Figure 2 illustrates the variation of speed-reducer torque with time for a counterbalanced pumping unit. Actual curves of reducer torque versus time are irregular in various ways, but the load variation and the relative position of load limits with respect to the average load are typical. Pumping speed ranges in practice from 4 to 30 cycles, or strokes, per minute. During each stroke, there are two peaks and two valleys. The valleys are usually negative, that is, occur at a time when energy is being transferred from the crank to the speed reducer. The ratio of peak load to average load depends on pumping conditions and ranges from 1.8 to 4.0.

MOTOR LOAD

THE LOAD ON a motor that drives a given pumping unit depends upon the electrical characteristic of the motor as well as the load cycle on the speed reducer of the pumping unit. High-slip motors vary more in speed with change in load than do normal-slip motors. The greater speed change causes the inertia of the rotating parts of the system to store more energy during the minimum load periods and release more energy during the peak load periods. The result is that input power peaks and over-all load variation are always less with 5- to 8-per-cent-slip motors and 8- to 13-per-cent-slip motors than with normal-slip motors. Averages of field measurements show that peak power input will be 25 per cent less than 5- to 8-per-cent-slip motors than with normal-slip motors.

Figure 3 is an example of the reduction in peak load and

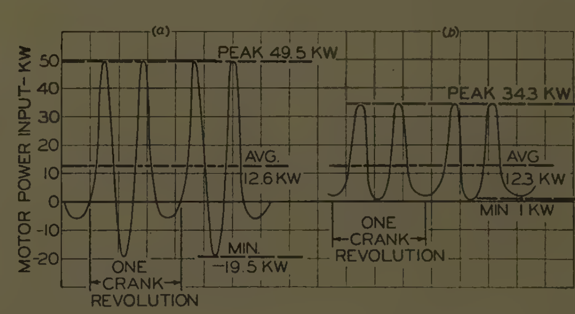

Figure 3. Change in motor load resulting from a change in the per cent slip of a motor. (A) Power input to a 25-horsepower normal-slip motor driving a pumping unit 22.2 strokes per minute; (B) Power input to a 25-horsepower 5- to 8-per-cent-slip motor driving the same unit 21.6 strokes per minute

Table I. Tests of Pumping Motors

	High Torque, Normal Slip	High Torque, 5 to 8% Slip
Number of tests	6	11
Average of rms currents in per cent of rated	99	95
Range of rms currents in per cent of rated	80 to 121	83 to 118
Average of power factors	0.499	0.698
Range of power factors	0.43 to 0.57	0.59 to 0.81
Average of derating factors	0.583	0.796
Range of derating factors	0.51 to 0.65	0.68 to 0.91

over-all load variation that resulted from changing the characteristic of the motor driving a given pumping unit from normal slip to 5- to 8-per cent slip. Power input limits and the time relationship of the limits are actual. Curves connecting the power limits are approximate.

Figure 3 and similar exhibits show that the use of high-slip motors instead of normal-slip motors will result in less fluctuation in line voltage and will result in lower peaks and less load variation on generating plants that are installed in the field to serve a group of oil-well pumping units. Other measurements are required to reach conclusions regarding the relative efficiency, power factor, and load-carrying capacity of normal-slip and high-slip motors when used as prime movers for pumping units.

LOAD CARRYING CAPACITY AND POWER FACTOR

Because of the high load peaks and wide load variation, motors that drive pumping units cannot continuously average an output equal to name-plate rating without being thermally overloaded. In other words, derating of motors is necessary to prevent thermal overload. Tests under actual pumping conditions are required to find the per cent of rated load that motors can average when driving pumping units. Measurements made on such tests must give either by direct reading or by calculation (1) rms current and (2) average motor power input. Rms current may be measured directly with a thermal ammeter. Average power input may be obtained from a watt-hour meter with a demand attachment or by calculation after first timing the disk on a watt-hour meter to get disk revolutions per minute. Having obtained rms current and average motor input, a measurement of terminal voltage will permit the calculation of power factor.

Measurements taken during 17 tests of motors driving pumping units gave results shown in Table I. Normal-slip motor sizes ranged from 20 to 60 horsepower. Motors with 5- to 8-per cent slip ranged from 10 to 60 horsepower.

Derating factor is defined as the ratio of average motor output on a pumping load to the output that the motor would develop on a steady load at the rms current measured on a pumping load. If rms current is near the rated motor current, the derating factor becomes the factor by which motor name-plate rating should be multiplied to give the average output that a motor can develop on a pumping load without being thermally overloaded.

For average oil-well pumping applications, the test data show that normal-slip motors can develop 58 per cent of name-plate rating and that the 5- to 8-per-cent-slip motors can develop 80 per cent of name-plate rating. For the most severe conditions, normal-slip motors can carry 51 per cent of rating whereas 5- to 8-per-cent-slip motors can carry 68 per cent of rating. Derating factors of 0.56 for normal-slip motors and 0.76 for 5- to 8-per-cent-slip motors are considered adequate for 85 to 90 per cent of all pumping unit installations.

Derating factors as determined from tests on pumping motors show that 5- to 8-per-cent-slip motors can average 35 per cent higher output per name-plate rating than normal-slip motors. Five- to 8-per-cent-slip motors cost 2 to 5 per cent more than high-torque normal-slip motors for sizes up to and including 20 horsepower and, with few exceptions, cost 15 to 17 per cent more than high-torque normal-slip motors in sizes above 20 horsepower. The net result is that 5- to 8-per-cent-slip motors give the oil producer 15 to 30 per cent more horsepower capacity per dollar invested than do high-torque normal-slip motors. This fact alone justified the purchase of 5- to 8-per-cent-slip motors for oil-well pumping.

Tests on 8- to 13-per-cent-slip motors are not available, but justification for their purchase in preference to 5- to 8-per-cent-slip motors is doubtful. Motors with 8- to 15-per cent slip cost 20 per cent more than 5- to 8-per-cent-slip motors and it is not likely that they will have as great a horsepower capacity per dollar initial cost as 5- to 8-per-cent-slip motors.

Power factor for 5- to 8-per-cent-slip motors was found on tests on oil-pumping operations to be 20 points higher on the average than the power factor for normal-slip motors. Therefore, the use of 5- to 8-per-cent-slip motors instead of high-torque normal-slip motors will either (1) reduce investment for capacitors if power factor correction is required, (2) permit smaller size of wire for line, or (3) result in less distribution system loss for the same wire size if power factor is not corrected.

MOTOR EFFICIENCY

The efficiency of high-torque normal-slip motors on steady loads is three to five points higher than the efficiency of 5- to 8-per-cent-slip motors. Which of the two types of motors is the more efficient on the fluctuating load encountered in oil-well pumping is still not known with certainty and is difficult to establish. To answer the question, tests must be made on many wells to determine the kilowatt hours used per barrel of liquid lifted by the two types of motors when pumping a given well at the same stroke and strokes per minute. Obtaining such tests is difficult because of the expense and down time required for changing motors, the difficulty of obtaining the motor sizes required to make the test with the two types of motors operating at near the same thermal load, frequent lack of facilities to obtain accurate production tests, and frequent inability to obtain motor sheaves to operate at the same strokes per minute with the two types of motors.

Results of tests on three different wells where kilowatt hours used per barrel of liquid lifted were determined with both normal-slip and 5- to 8-per-cent-slip motors are given in Table II. These tests were made in an oil field where the productivity of individual wells was practically constant. The time between tests with the two types of motors on a given well ranged from three to five days.

Lift efficiencies of normal- and 5- to 8-per-cent-slip motors were practically the same on the tabulated tests. Therma

ad for the two types of motors was nearly the same uring only one of the tests and there was some difference strokes per minute in all cases. Until sufficient tests e made to show a trend one way or another, the efficiencies normal-slip and 5- to 8-per-cent-slip motors will be onsidered equal for oil-well pumping applications.

MOTOR PROTECTION

RDINARY thermal overload relays will not protect 5- to 8-per-cent-slip motors from stalled single phase. his is not necessarily a disadvantage because stalled ngle phase is prevented by either one or the other of two evices that are usually incorporated in oil-well motor ontrols. One of these devices is the undervoltage relay. he other is the time-delay relay, a device that is used to art motors automatically one at a time after restoration power following an interruption. Where a time-delay elay is used, the coil of the magnetic switch is connected cross one phase and the time-delay relay is connected cross another phase. Then the elements will not pick p after an outage until 3-phase power is restored.

SINGLE-PHASE MOTORS

HERE ARE instances where only single-phase power is available. Types of single-phase motors that can be sed for oil-well pumping service include capacitor start, nduction run; repulsion-induction; repulsion start, in-uction run; and 2-value capacitor, sometimes called apacitor start, capacitor run.

The 2-value capacitor motors are preferred for oil-well umping service. These motors have electrical charac-eristics similar to 3-phase high-torque normal-slip motors; ney are as simple in construction as 3-phase induction otors, operate with 8 to 20 points higher power factor than ther types of single-phase motors, and sell for the same rice as other types of single-phase motors.

FRAMES

UMPING MOTORS are installed in the open to simplify the entire installation and reduce installation cost. ypes of frames that are available for outdoor service nclude totally enclosed fan-cooled; splashproof; protected ame; and dripproof. The various frames obviously give ifferent degrees of protection against entrance of water, ut experience has shown that all of these are satisfactory r outdoor service with the possible exception of the rare nstances where motors may be buried in snow. Some perators believe that housing is justified where motors ay be covered with snow. Water will enter dripproof otors during driving rain storms. This has not been und to cause winding deterioration provided provision made for drainage of water out of the motor.

able II. Determination of Energy Used to Pump One Barrel of Liquid

	Stroke, Inches	Strokes per Minute: Normal	Strokes per Minute: 5 to 8%	Rms Current in Per Cent of Rated: Normal	Rms Current in Per Cent of Rated: 5 to 8%	Kilowatt Hours per Barrel: Normal	Kilowatt Hours per Barrel: 5 to 8%
ell A	110.8	18.6	17.7	110	84.6	0.528	0.525
ell B	44.5	20.7	20.3	68.5	61.8	0.499	0.503
ell C	21.9	17.3	17.0	98.2	81.3	0.633	0.636

Table III. Capacity per Dollar Invested

	Protected Frame and Dripproof	Splashproof	Totally Enclosed, Fan-Cooled
Rated temperature rise, degrees centigrade	40	50	55
Relative horsepower capacity	1.00	0.895	0.853
Relative initial cost	1.00	1.08	1.38
Relative horsepower capacity per unit cost	1.00	0.83	0.62

In some areas, for example the Borger Field in the Texas Panhandle, rodents will build nests in the air passageways of motors installed on pumping units. Air inlet and outlet openings of any type of motor must be covered with $^1/_4$-inch mesh screen where this condition exists.

Users will get the most horsepower capacity per dollar invested by purchasing protected-frame or dripproof motors. Specifically, dripproof and protected-frame motors have 20 per cent more horsepower capacity per dollar initial cost than splashproof motors and 61 per cent more capacity per dollar initial cost than totally enclosed fan-cooled motors. Derivation of the percentage figures is given in Table III.

Horsepower capacity per unit cost for dripproof and protected-frame motors compared to splashproof $=1.00/0.83=1.20$. Horsepower capacity per unit cost for dripproof and protected-frame motors compared to totally enclosed fan-cooled $=1.00/0.62=1.61$.

In addition to giving users the greatest capacity per dollar invested, the 40-degree-centigrade protected-frame and dripproof motors have a service factor of 115 per cent. This is a very desirable feature in view of the type of load encountered in driving pumping units.

VOLTAGE RATING

THE MOST widely used voltage rating for oil-well pumping motors has been 440 volts. This voltage rating has been adequate for loads up to 25 horsepower and for installations where the distance between wells did not exceed 660 feet, the distance between wells on 10-acre spacing. For loads greater than 25 horsepower and where the distance between wells is greater than 660 feet, a voltage rating between 440 and 2,400 volts would be desirable provided the cost of motors and controls for the intermediate voltage would not more than offset savings in the cost of distribution lines.

To obtain an operating voltage between the 440 and 2,400 volts without paying premium prices for motors and controls, the Humble Oil and Refining Company has made a number of installations where 440-volt motors were Y-connected to operate at 760 volts. Performance of the 760-volt system has been reported to be satisfactory when the motor neutrals have been grounded, thereby limiting the maximum voltage to ground on any portion of the motor to 440 volts.

Consideration of the 760-volt system is recommended for installations where motors will be larger than 25 horsepower, and where the distance between wells will exceed 660 feet. This recommendation is made because the trend is toward wider spacing of wells.

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Simplified Subscriber Toll Dialing

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As MORE and more telephones are converted to dial, the elimination of operators presents the problem of automatically preparing billing information for toll calls between dial exchanges. A practical solution appeared to be an automatic ticketing trunk on which a billing record can be prepared at the same time as the connection is established.

Low cost necessitates thought along different lines from automatic ticketing systems in present use. Distinguishing features of this new system are:

1. Calling station identifies itself by the subscriber dialing his own number.
2. The recorder is a simple tape punch mechanism perforating a single row of holes.
3. Direct recording—no translating.
4. Each trunk has its own recorder to eliminate storage and connecting circuits.

A check is provided to verify that the dialing was received from the line indicated. The method of recording information uses the dialed pulses without any translation, each digit being represented by a line of holes perforated along a tape. The recorder consists of a punch magnet and a stepping magnet to feed the tape.

The equipment involved in the automatic ticketing system is shown in Figure 1. The timer and calendar can be common to an entire office. Trunk terminations consist of relay circuits involving relatively few relays above those required for normal operation of the trunk system.

To place a call, a subscriber first dials the trunk code, then his own number, and then the number at the distant exchange. Other functions are the same as on local exchange calls.

Upon dialing a trunk code, the trunk seizes a check link. When the subscriber dials his own number, the impulses are registered on the recorder and also operate the check link. At the completion of the dialing, the trunk circuit "flashes" the regular link. This supervision is picked up by the check link and carried back to the trunk to verify the identity of the calling line. If an incorrect number has been dialed, then there is no connection through the check link and the signal is not received. Busy tone is returned and further dialing is blocked. Immediately after the check has been made, the check link is released.

Figure 1 shows the path of verification with a regular link by solid line or with a special link by means of a dotted line.

Answering the call starts the timer and punches one hole in the tape. At each successive minute, another hole is punched. The total number of holes represents the total chargeable time.

Upon release, the exchange links are released, but the trunk and recorder are held for the calendar, which records date and time of day before releasing the trunk.

In the design of the trunk and recorder, simplicity and low cost were of prime consideration. In translating this information for billing purposes, more latitude is available. The following methods are possible:

1. Directly count the perforations on the tape, perhaps using an indicator to show the number of perforations without requiring physical counting.
2. Feed the tape through a simple mechanical or photoelectric sensing device which converts the impulses so generated to actuate a display panel of registers so that this information may be copied on ticket, or automatically photographed.
3. Translate the information from the sensing device to operate circuits which would prepare standard business machine punch cards to be used in automatic accounting.

The equipment used would depend upon the volume of tapes to be handled.

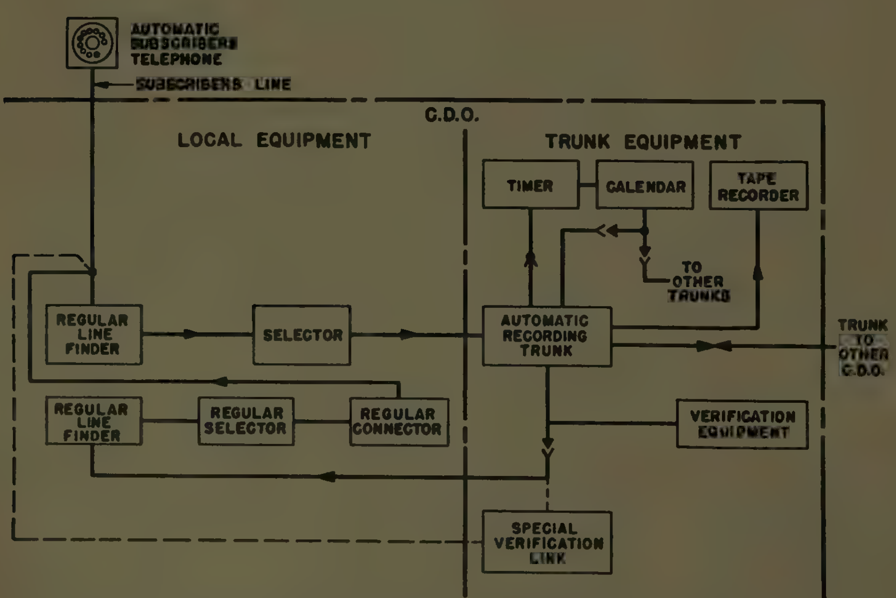

Figure 1. Block diagram of automatic ticketing trunk and checking link

Digest of paper 50-227, "Simplified Subscriber Toll Dialing for Low-Rate Low-Density Toll Circuits Between CDO's," recommended by the AIEE Committee on Communication Switching Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Published in AIEE *Transactions*, volume 69, part II, 1950, pages 1417–20.

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Thermal Transients on Buried Cables

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THERMAL TRANSIENTS on cables have an important bearing on the emergency rating of a cable, matter which is receiving increasing attention because its economic as well as its technical importance.

The problem of thermal transients on cables in air has een solved; and formulas are available by means of hich such transients can be calculated to any desired egree of precision, if the necessary constants are known.

In the case of directly buried cables, however, while everal formulas are available, they are either semiempirical 1 character (like the simple exponential formula and the xponential series formula), or, if derived mathematically, ney are based on simplifying assumptions which represent ctual operating conditions only approximately. The xponential integral formula (and the Ingersoll integral rmula which gives the same results) are based on a line ource of heat and its image. These formulas are satisctory for large values of time, but not always for small alues.

Carslaw and Jaeger[1] have presented more complicated rmulas, based on a cylinder source with and without inernal thermal capacity; and Knudsen[2] has proposed for a asic assumption the use of two Bessel cables in series, one represent the cable and the other the surrounding earth. nudsen's assumptions leave nothing to be desired from ne standpoint of accuracy; unfortunately, he does not now how to apply them when the second Bessel cable representing the earth) is infinitely long.

A new formula has been developed based on the asumptions shown in Figure 1. The cable, approximated y lumped constants, is placed in series with an infinite essel cable representing the earth. The effect of the arth's surface may be taken into account by a suitably laced image. Equations are developed for the copper emperature T_c, the surface temperature of the cable T_r, nd the temperature at any point in the earth surrounding ne cable T_x.

These formulas, while practical for refined calculations, re unfortunately too complicated and too difficult to pply in everyday work, where speed is important. They re, however, of value as a standard of comparison, whereby ne accuracy of other and simpler formulas may be corectly judged. By using these new formulas, it has been ound that the exponential integral formula, with a suitable mpirical correction term as shown in equation 1, is acurate enough for most practical work.

$$T_r=\frac{W_0p'}{4\pi}\left[-Ei\left(\frac{-r^2}{4kt}\right)+Ei\left(\frac{-D^2}{kt}\right)\right]\left[1-\frac{p'Q}{4\pi t}e^{-r^2/4kt}\right] \quad (1)$$

In equation 1, T_r is the cable surface temperature in egrees centigrade; W_0 is the loss in the cable in watts er centimeter; p' is the soil thermal resistivity, degrees entigrade-centimeter per watt; r is the cable radius 1 centimeters; k is the thermal diffusivity of the soil square centimeters per second units; t is time in seconds; Q is the thermal capacity of the cable (or pipe) and its contents in watt-seconds per degree centigrade per centimeter.

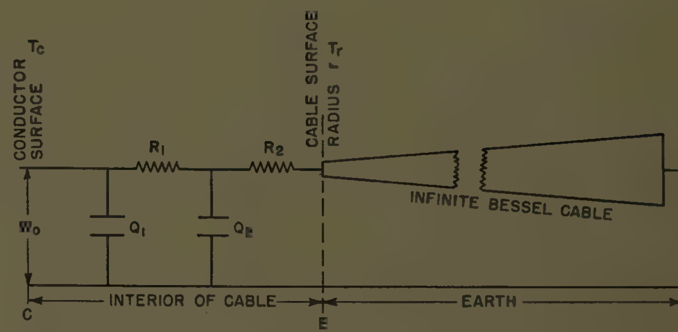

Figure 1. Equivalent circuit of cable buried in infinite earth

A simple formula involving the addition of exponential terms to the cable surface temperature suffices for the calculation of the copper temperature with sufficient accuracy for practical purposes. This is equivalent to adding the effect of the thermal resistances and capacitances inside the cable directly to T_r as though they were independent of T_r. The exact and approximate formulas agree very well with tests; the discrepancy between the exact and approximate formulas is small enough to permit the use of the approximate formula with acceptable accuracy for most everyday calculations.

The following conclusions were reached:

1. All present techniques for calculating temperature transients on buried cables have theoretical limitations.
2. A more accurate formula has been developed in which these theoretical limitations are overcome. While too complicated for an everyday working formula, it forms an acceptable standard of comparison against which such formulas can be checked.
3. The exponential integral formula, with a simple correction factor, is a good formula for calculating T_r.
4. Copper temperatures may be calculated with fair accuracy by adding the effect of the thermal resistances and capacitances inside the cable directly, as though they acted independently, and neglecting coupling between the earth part of the circuit and the interior of the cable.
5. The formula does not apply to cables in ducts.

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The Goerges Phenomenon

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THE INDUCTION motor with unbalanced rotor resistances was first studied by Hans Goerges more than 50 years ago.[1] Early investigations were concerned with one particular phase of the problem: the single-phase rotor. It was found that the wound-rotor motor with one rotor phase opened could be operated stably near half-speed, either as motor or generator. A singular feature noted by Goerges was that the efficiency of the motor with single-phase rotor was much higher than that of the balanced motor operated at the same speed with external resistances. Subsequent study of the problem has been motivated by the need for a simple method of speed control. Rotor unbalance has had to be considered in the application of resistance controllers for speed variation and starting, because this equipment usually is unbalanced at many of the stepped positions.

This unbalance problem can be analyzed by the use of symmetrical components, since this method is particularly suited to multiphase problems in which the electrical quantities are only partially unbalanced. The only unbalance is here introduced at the slip rings of the motor. The slip-ring voltages may be resolved into positive and negative sequence components, and an equivalent circuit derived for each sequence in the same manner as for the conventional treatment of the balanced induction motor. If two of the external rotor impedances are equal, one equivalent circuit is obtained from which all motor sequence currents can be related, as shown in Figure 1, where Z_b and Z_c are two equal external impedances, I_1 and I_2 are respectively positive sequence stator and rotor current of applied and of slip frequency, I_3 is negative sequence rotor current of slip frequency, and I_4 is negative sequence stator current of a lower than supply frequency which is impressed into the power supply lines as a result of the unbalance. After these sequence currents are found, current, input, electrical torque, and losses may be calculated readily.

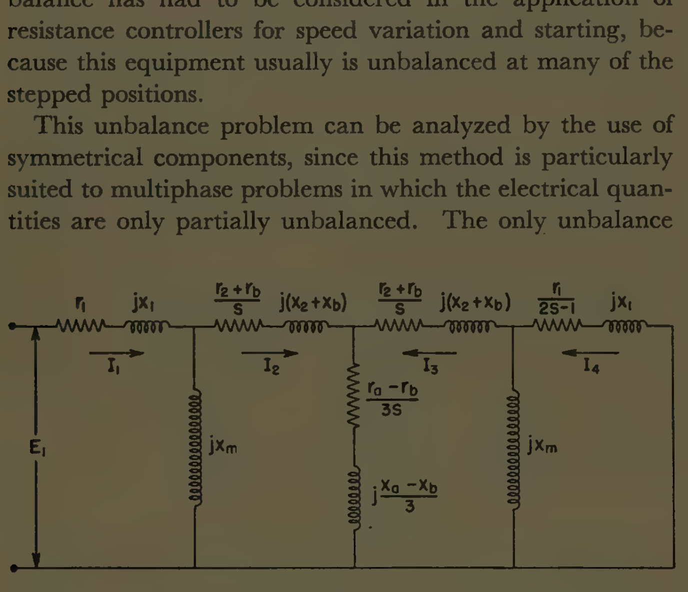

Figure 1. Complete equivalent circuit for two equal impedances in the rotor circuit

Tests were made in the laboratory at Illinois Institute of Technology, Chicago, Ill., on a motor-generator set having a 5-horsepower induction motor. Results for one condition of unbalance are shown in Figure 2, with electrical torque versus speed given for several values of an external resistance in one rotor phase. Because of the limited capacity of the coupled machine, tests could not be made in the unstable region, and the curves have been approximated there. The tests agreed very well with calculated characteristics based on the equivalent circuit. It is seen from Figure 2 that as R is decreased, the torque-speed curve becomes more nearly like that of the balanced rotor. The tests and calculations showed that several conditions of rotor unbalance exist which give a high torque at reduced speed without exceeding the motor rating.

It is found that desirable characteristics of the motor with unbalanced rotor are: stable operation at two speeds—near-half-speed and near-synchronous-speed; a high operating efficiency at half-speed; and the possibility of greater speed variation available for intermittent or for emergency operation. Disadvantages are: the low power factor; decreased pull-out torque; subfrequency currents impressed into the supply lines; and vibrations caused by pulsating torque.

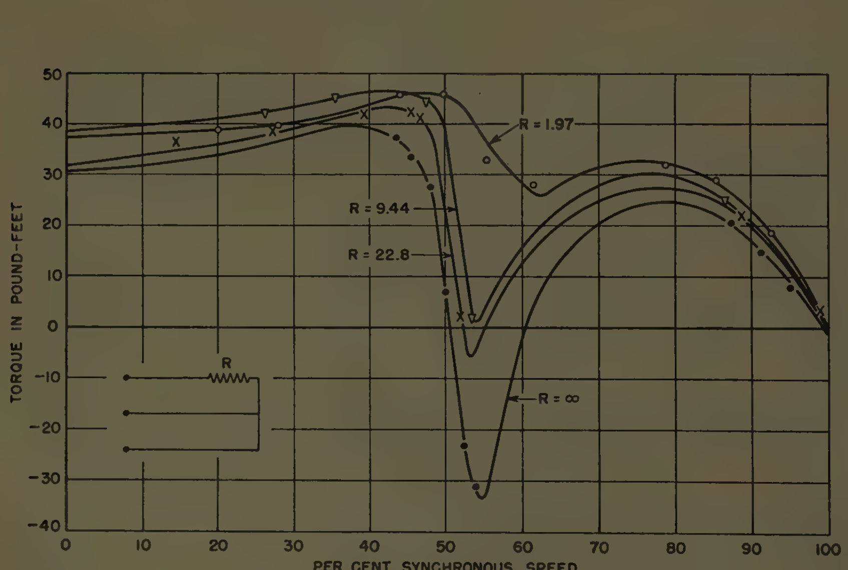

Figure 2. Torque-speed characteristics obtained from tests with external resistance in one rotor phase (R is referred to stator)

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Systematization of Tube Surveillance in Large Scale Computers

H. W. SPENCE

Ninety per cent of the service interruptions of ENIAC at Aberdeen Proving Ground are caused by vacuum-tube failures. A 5-month tube surveillance program was conducted wherein faulty tubes were detected and replaced. How such tubes were tested and their histories gathered is described together with the preliminary findings.

THE ENIAC, a high-speed electronic computing machine, was designed in the most conservative manner possible known at the time. However, oper-ting experience at the Computing Laboratory of the Ballistic esearch Laboratories has shown that a more thorough nowledge of the behavior of systems involving large umbers of vacuum tubes would have led to different esign procedures.

To correct certain unforeseen defects in the ENIAC and accumulate data for guiding the designing of new equip-ent and tube-testing proce-ures, a program of detailed ube surveillance was inaugu-ated at the beginning of 1950. ystematic records are kept y recording all the informa-ion relating to the service fe of each tube on punched ards. One card is used per ube. Items recorded on the ard are: the tube type, kind f use, hours of life, manu-acturer, panel location, type of failure, previous service, reheating schedule, date, and test readings. This system ermits great flexibility in processing the information by neans of standard International Business Machines equip-nent and by the ENIAC itself.

In general, certain unusual conditions are present in this rogram which should be noted before applying the results f this study to other operations. First, both the filament nd plate voltages are applied at all times and the system in operation 144 hours per week. This procedure has een established because it provides the most economical tilization of the equipment. Second, all the tubes in a aulty circuit are replaced at once and those removed from he system rechecked. Bad and marginal units are dis-arded.

In the other types of service wherein only failures are emoved from service and marginal elements are not, onger service life would be achieved.

TUBE REPLACEMENT AND TESTS

THERE ARE approximately 18,000 tubes in the ENIAC. They are divided according to types as follows: 35 per ent are *6SN7*'s, 22 per cent *6L6*'s, 14.1 per cent *6SA7*'s, 8 per cent *6SJ7*'s, 6.5 per cent *6L7*'s, 1.6 per cent *6J5*'s, 7 per cent *6V6*'s, 1.6 per cent *6Y6*'s, 2.5 per cent *6AC7*'s, and 1.8 per cent *807*'s. Blanket changes in such a large number of tubes are impractical because the incidence of failures during the first 1,000 hours of life greatly exceeds the failure rate that exists after this period. On the other hand, replacing one tube at a time is undesirable because isolation of a single faulty tube requires expensive time-consuming tests. A compromise between these two extremes is most economical. When a malfunction is discovered, it is traced to a particular circuit. Then all the tubes in the circuit are replaced; there may be one to eleven tubes in this group. This procedure eliminates bad combinations of marginals as well as complete tube failures. Satisfactory elements are removed also. Therefore, it is necessary to test all removals. Good units are placed in storage; marginal and bad elements are discarded. Faulty circuits are detected by means of two types of control tests.

Operational tests, utilizing a check problem, detect malfunctions by comparing the result to a known correct answer. These tests are used for two purposes: first, for marginal checking, that is, the detection of weak tubes; second, as a guide to machine condition during long periods of problem operation. Marginal checking is achieved by increasing the speed of machine operations. This is accomplished easily in the ENIAC because of the synchronization of operations by a central pulse system. A pulse rate of 125 kc is used for this type of checking. Operational tests, used as an indication of machine condition, consist of sample calculations of the problem being solved and are made periodically under normal operating conditions. Normal operation involves the transfer of information pulses at rates which range between 60 and 100 kc.

Oscilloscope tests are used to inspect and measure pulses. Corrective action is taken when these pulses do not conform to the prescribed shape or amplitude. The acceptance limits are set above the operational level necessary for correct circuit performance. Oscilloscope tests are more satisfactory than the operational tests for preventive maintenance; however, they are difficult to devise so that machine time is conserved. All tests are run at least once a week or as the need is indicated by the operational tests.

ssentially full text of paper **51-84**, "Systematization of Tube Surveillance in Large cale Computers," recommended by the AIEE Committee on Computing Devices and pproved by the AIEE Technical Program Committee for presentation at the AIEE Vinter General Meeting, New York, N. Y., January 22–26, 1951. Scheduled for pub-cation in AIEE *Transactions*, volume 70, 1951.

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When oscilloscope tests are used for detection, defective tubes are removed sooner than with operational tests.

TUBE STANDARDS

THE ROUTINE which has been established for handling tubes from the time they are received until they are discarded is shown in Figures 1 and 2. Voltage is applied to the filament of a new tube for a minimum of 50 hours. It then is tested and may be rejected or passed. Good tubes are color-coded to designate the type of service in which they will serve and are stored until used in the machine.

When a tube is placed in service in the computer, the reading of an hour counter, incorporated in the equipment, is stamped on the envelope. It stays in service until it is removed because of circuit failure and then is placed in a panel collection box. The tube is tested then and either discarded or reclassified and sent to the reserve storage. There are three general classes of tests. They disclose the condition of emission and cutoff and the presence or absence of short circuits.

The emission tests measure the current flow to the plate and screen with the control grid or grids at cathode potential. The voltages and currents specified in the standards have been established by experience and are shown in Table I.

Tests to determine tube performance when grids are operated at certain prescribed potentials are performed as follows:

1. Measure the plate current at cutoff voltage of the first grid, the third grid being at cathode potential.
2. Measure the plate current at cutoff voltage of the third grid, the first grid being at cathode potential.
3. Measure the plate current with both the first and third grids at cutoff voltage.
4. Measure the screen current at the cutoff voltage of the first grid.
5. Measure the ion and leakage current of the first grid with it at cutoff voltage.
6. Measure the ion and leakage current of the third grid with it at cutoff voltage.

Table II shows the cutoff voltages and maximum currents used. The plate and screen voltages for these tests are

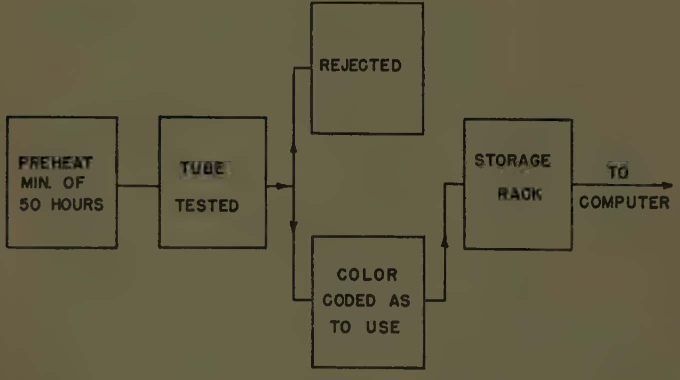

Figure 1. Path followed by tubes before installation in the computer

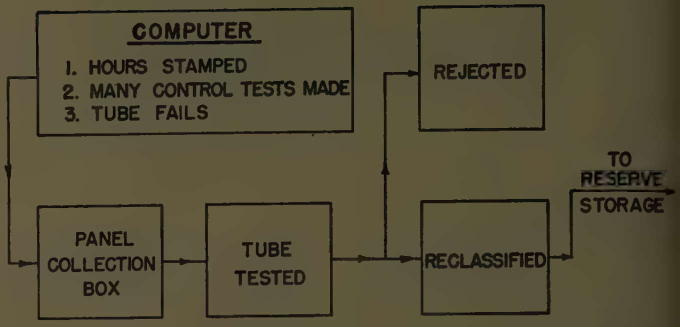

Figure 2. After testing in the computer, tubes which fail are either rejected or reclassified

identical with those used in the emission tests shown in Table I.

The short-circuit tests measure the current flow with −100 volts between each element and all other elements connected together. The cathode-to-filament tests are made by impressing +100 volts between them. The permissible leakage current for the *6L6*, *6SJ7*, *6SA7*, *6SN7*, *6AC7*, and *6J5* tubes is 17 microamperes. The test for the *6L6*, *6V6*, *6Y6*, and *807* tubes is the same except for the heater cathode leakage where the maximum permissible current is 36 microamperes.

TUBE HISTORY

AFTER A tube has been discarded, its history is noted in a log book and is transferred later to punched cards. The tube type, kind of service, manufacturer, type of failure, test readings, and date are recorded. The color-coding system, mentioned before as designating the type of service, divides the tubes into seven classes—four being specific circuits and three being types of circuits. The color code and the panel position identify the exact circuit in which the tube functioned in 80 per cent of the cases. The remaining 20 per cent can be identified as having functioned under certain maximum and minimum conditions. Collection boxes, which have been placed at the rear of each panel, keep the removals separated with regard to their panel position.

The reading from the hour counter at the beginning of each week is stamped on the envelope of new tubes placed in service. At the end of each week, the collection boxes are emptied and the meter reading noted, thus establishing the service life of the tube. The greatest error in the number of hours of service life assigned to a tube is 218, which occurs when the tube is placed in operation just after all the new tubes have been marked and then removed just before the tubes are gathered up. Very seldom is the error this great since a preventive testing procedure is followed every Monday morning making fewer tube failures occur during the early part of the week.

PRELIMINARY RESULTS

SOME 5,000 tubes were removed and discarded from the ENIAC during the first five months of 1950. This is an average of 250 tubes per week, 70 per cent greater than the 1949 average. The increase is due to an extensive overhaul of the machine that was conducted during this

eriod and improved testing procedures. The average ervice life for tubes discarded during the period is shown n Figure 3.

The *6Y6*, *6J5*, *6SN7*, and *6SJ7* types had the highest verage service life, ranging from 10,600 to 12,400 hours, hile the *6AC7* and *6L6* types ranged from 5,800 to 6,600 ours. This average service life of the tubes should be eighted by the following considerations: the kind of ervice, the type of test used to detect the faulty tube, and he degree of safety factor in the circuit where it is used.

It is known that some circuits in the ENIAC will funcion satisfactorily even though their tubes have a reduction n plate current as great as 40 to 50 per cent of the test tandards. These tubes will have a longer service life due rincipally to the circuit design. Unfortunately, other ircuits do not allow as great a reduction in the plate curent and therefore tubes are removed much sooner, making ervice life less.

The *6J5* and *6SN7* tubes are used with a maximum plate otential of 150 volts. When used in the OFF condition, he grid voltage is three times the cutoff voltage. Used in he ON condition, the grid is sufficiently positive to draw ome emission current. The average service life for the *J5*'s was 11,900 hours and for the *6SN7*'s was 11,000 hours. The *6J5* is used only in the OFF position, but the *6SN7* is sed in three different ways: both halves of the tube conlucting, both halves nonconducting, and one half conlucting and the other half nonconducting.

Of the *6SN7* ring tubes rejected in the last five months, 0 per cent failed because of low emission. When *6SN7* ubes are used in ring circuits, where one side of the tube is ormally conducting and the other side is not conducting,

able I. Standard Voltages and Currents Used to Determine Emission Characteristics

ube ype	Voltage in Volts: Plate	Voltage in Volts: Screen	Minimum Current in Milliamperes: Plate	Minimum Current in Milliamperes: Screen
Y6	150	40	15	0.485
L6	150	75	28	1.0
V6	150	75	19.5	0.9
L7	150	75	5	6.0
SA7	150	75	5	7.5
SJ7	150	75	5	1.25
AC7	150	21	0.3	0.05
07	190	190 through 20,000 ohms	50	3.0
J5	75		5	
SN7	75		5	

able II. Standard Voltages and Currents Used to Determine Cutoff Characteristics

ube ype	Cutoff Voltages: Grid 1	Cutoff Voltages: Grid 3	Maximum Plate Current, Milliamperes	Maximum Screen Current, Milliamperes
Y6	−9.5		2.0	0.000070
L6	−11.0		4.0	0.14
V6	−10.0		3.0	0.13
L7	−12.0	−8	0.7	0.85
SA7	−7.0	−14	0.7	1.00
SJ7	−5.5	−50	0.7	0.000170
AC7	−2.0		0.04	0.000007
7	−100.0		0.000020	
J5	−4.5		0.7	
N7	−4.5		0.7	

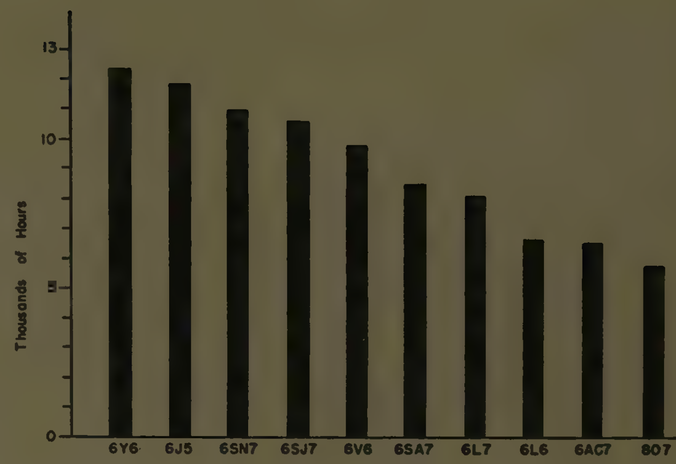

Figure 3. The average life of ten tube types tested varies from 5,500 hours for the 807 to 12,500 hours for the 6Y6

the conducting side has a much higher average test plate current than the nonconducting side. The *6SN7*'s also are used in the same manner in a pulse-shaping circuit where the same results were obtained.

Of all other tube types used in the OFF condition, except the *807*'s, 85 per cent were discarded because of low emission. The number of tubes used in the ON condition and discarded for low emission ranges from 1 per cent to 66 per cent for any one type tube. The life of the tubes used in the ON condition as compared with the same type used in the OFF condition is better by a factor of 50 per cent or more when only the low-emission type failures are considered.

All the *6SJ7*'s, *6L7*'s, and *6SA7*'s are used as normally OFF tubes and all have low emission as the predominant type of failure. Their average lives are 10,600, 8,100, and 8,500 hours respectively. The *6SA7*'s are used in two ways. One which has a duty cycle ten times that of the other has a longer average life by 1,600 hours.

For all tubes in the ENIAC, except the *6SA7* and the *807*, the tube lives terminated by low-emission failure averaged more than twice as long as those terminated by failure due to poor cutoff, short-circuited elements, and burned-out filaments combined. The *6SA7* showed the same trend as the others but to a lesser degree.

The *807* showed the reverse of this condition to be true with low emission being 38 per cent less than all others. This behavior may be explained by the fact that these tubes operate with excessively high plate potentials.

The *6Y6* tube, having an over-all life average of 12,300 hours, is used only as a triode. In one circuit nine such tubes are connected in parallel. This makes it difficult to determine when one tube is faulty because the safety factor in the circuit will allow it to function when one or two tubes are well below standard. Detection being difficult, a longer service life results. The type of malfunction most prevalent is short-circuited elements, the heater-cathode short being the most common. It is interesting to note that this failure does not cause the computer to malfunction because the heaters are at cathode potential.

The *6AC7* and *807* have life averages of 6,500 hours and 5,800 hours respectively. These tubes are used in a type

of circuit where the safety factor is small. The circuits are given extensive marginal tests every three or four months. Tubes are removed which are not causing circuit failures but indicate they will in the near future. The two conditions—low safety factor and extensive testing—cause lower service averages for these two tube types.

The *6AC7*'s which are used in the ON condition with plate, screen, and grid potentials of +80, +20, and +1 volts respectively, fail 99 per cent of the time because of short-circuited elements or unsatisfactory cutoff conditions.

The *807*, which is used mainly in the OFF condition, with 600 volts applied to the plate and both grids at below the cutoff point specified in the test standards, has 40 per cent of its failures due to short-circuited elements. A reason for this may be that the duty cycle of this *807*, even though it is classified as a normally OFF tube, is high because of the manner in which its circuit is used. It is ON for 300 microseconds at a time and is used many more times than any other normally OFF circuit in the ENIAC.

The *6L6* is used in both the OFF and ON condition with a low service life average of around 6,300 hours. For the OFF type of service, the low emission was the predominant type of failure, while for the ON use it was about 50 per cent low emission and 50 per cent cutoff, short-circuited elements, and burned-out filaments combined. The average life for an ON tube with a low-emission failure ran 10,200 hours, which is 70 per cent better than the life average for a low-emission failure in an OFF tube.

Improving the Position of Electricity as Primary Energy for Space Heating

CLARENCE FRERE

Low-temperature radiant-panel heating offers a possible solution to the problem of house heating by electricity. Some of the technical and economic aspects are discussed.

MANY YEARS AGO, Dr. Charles P. Steinmetz stated that some day our homes would be built without chimneys and heated entirely by electricity. Today, we are rapidly approaching an economic and practical realization of this prophecy.

More than 50,000 homes now use electricity as the sole source of heat. It is true that not all electric heating installations in operation are competitive with combustion methods of heating from an operating cost standpoint, yet the users of these systems are satisfied and must believe that the many advantages gained outweigh the higher cost of operation.

There are a number of requirements from a user's standpoint which pertain to any successful design of residential heating equipment. These can be enumerated in order of importance as: (1) the equipment must be of benefit to the customer in helping him to enjoy greater convenience and comfort; (2) it must possess economy of operation; (3) it must be completely safe; (4) it should be free of service problems; (5) it must be practical in its application; (6) the system should possess flexibility of control; and (7) its appearance must be acceptable.

METHOD FOR APPLYING ELECTRIC HEAT

HUMAN COMFORT, when considered from a thermal point of view, is dependent on four basic physical conditions: mean radiant temperature of the enclosing surfaces, ambient air temperature, direction and intensity of any air movements, and relative humidity.

It is generally agreed that the average surface temperature over the approximately $19^1/_2$ square feet of radiating area of the clothed human body is 83 degrees Fahrenheit. Laboratory experiments have shown that a normal subject can be comfortable in a room which has an air temperature of 57 degrees Fahrenheit, if all the surrounding surfaces are kept at a temperature of 83 degrees Fahrenheit. Other laboratory tests have been made in which the occupant was placed in a room having 100-per cent reflective surfaces, air temperature at 60 degrees Fahrenheit, and with the surrounding surfaces at a temperature of 5[?] degrees Fahrenheit. In the latter test, the subject was kept comfortable by restricting the radiant losses.

These laboratory experiments illustrate a principle of heating which it is thought can improve the competitive position of electric heating. The primary problem is to provide a practical means for applying radiant energy in our living environment and to distribute this energy source so as to provide irradiation at low intensities from a large area and from many directions.

With low-temperature panel warming, the mean radiant temperature of the room is varied by controlling the tem

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rature of a large portion of the enclosing surfaces. inel heating is the means for providing irradiation at w intensities for a large area and from many directions. ich a system dispenses with the high-intensity irradiation nich is characteristic of spot radiant reflector or unit-pe convector heaters commonly used today. With a ore uniform radiant and controlled receiver surrounding , body comfort can be maintained at lower air tem-eratures. With conventional heating systems, air is eated which expands and rises, causing air currents or afts, and this action causes a considerable temperature adient throughout the room. Contrasted with this stem, a panel system makes no attempt to heat the air, it rather to heat the enclosing surfaces and objects in the om. The result is a very even heat distribution through-it the room, and the temperature gradient is nearly iminated. While this arrangement with lower air tem-eratures would seem to hold many possibilities, in prac-ce this depression of the air temperature amounts to ily about five to eight degrees Fahrenheit. This limitation due to secondary effects which occur after the first energy lease.

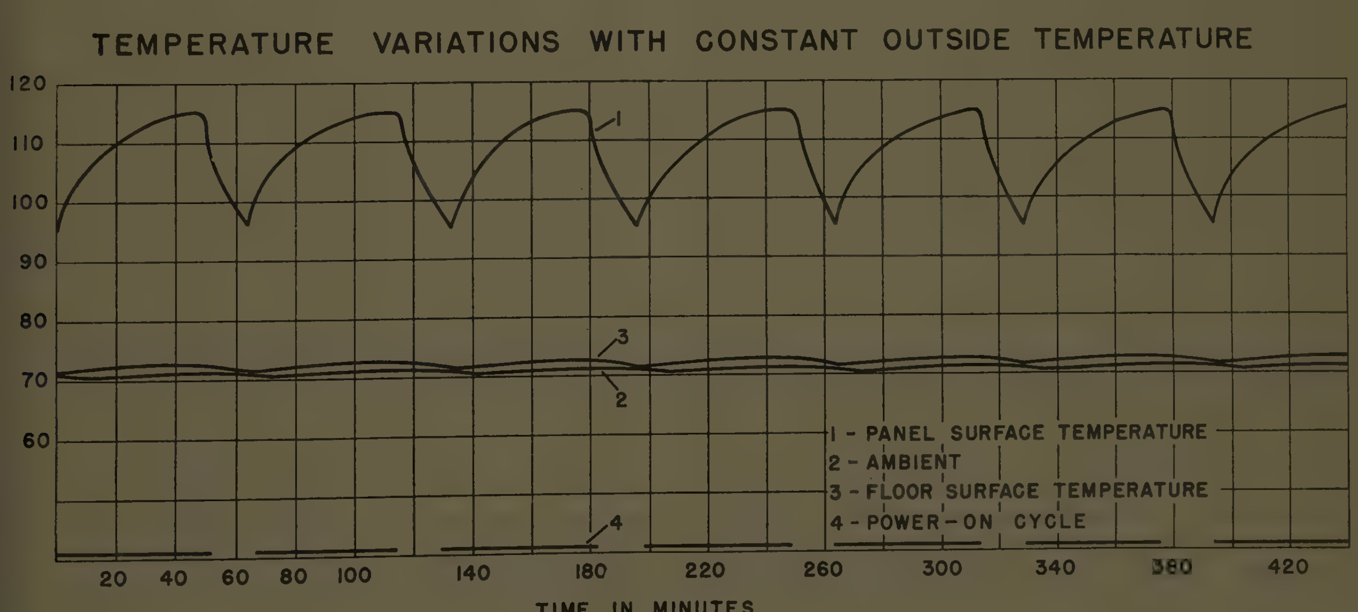
A panel-heating system requires no control adjustment r varying climatic conditions. With conventional heat-g, indoor air temperature must be increased continually outdoor air temperatures drop. This is a manual change the thermostat since no provisions have been made to ilance the room conditions as the walls become colder. s outdoor air temperatures go down a panel system main-ins comfort conditions by changing the panel temperature well as the enclosing surfaces. The air temperature oes not change, and in many cases it actually may drop ightly.

For the most part, panel-heating systems today comprise warming panel made by embedding a serpentine pattern hot-water pipes (in some cases an electric conductor) in a concrete floor slab or in the plaster. With these systems, the quantity of heat which goes into storage is relatively high. It is not surprising, therefore, that the main disadvantage of a hot-water-panel system is admitted to be slow response to weather changes. Panel heating by electrical means is a natural application. With electric-panel-heating equipment, this difficulty of high thermal mass is eliminated and there no longer is need for plaster or other building materials to form the heat exchanger. The heating element itself is the emitting surface. Flexibility of control unobtainable with any other house heating equipment is a distinct advantage of electric panel heating and this flexibility, while providing maximum body comfort, also enables more operational savings by elimination of overshoots. (See Figure 1.)

APPLYING ELECTRIC HEATING ECONOMICALLY

As a possible solution to the problem of improving the competitive position of electric house heating, several years have been spent in developing a low-temperature radiant-panel-heating system. It was desirable to have a system which would possess the many advantages of panel heating, and yet be a practical means of doing the job electrically. It was determined that the application of electric heating must be in the form of a completely prefabricated unit in which the design characteristics would be predetermined, and not left to happenstance. It was further desired to have equipment which could be used in existing structures when applicable, requiring no more than redecorating the room in which it is installed.

The equipment developed is a very thin wafer-like panel structure having a thickness of approximately 30 mils. The construction consists of a copper-alloy wire element sandwiched in a phenolic laminate. Because it was believed that an electric heating system should be grounded, both sides of the phenolic sheet have been covered with a



gure 1. Temperature variations of an electric panel operation in a room with four exposed walls. Constant outside temperature 17 degrees Fahrenheit, attic temperature of 42 degrees Fahrenheit, cellar temperature of 64 degrees Fahrenheit, and mean radiant temperature of 74.7 degrees Fahrenheit

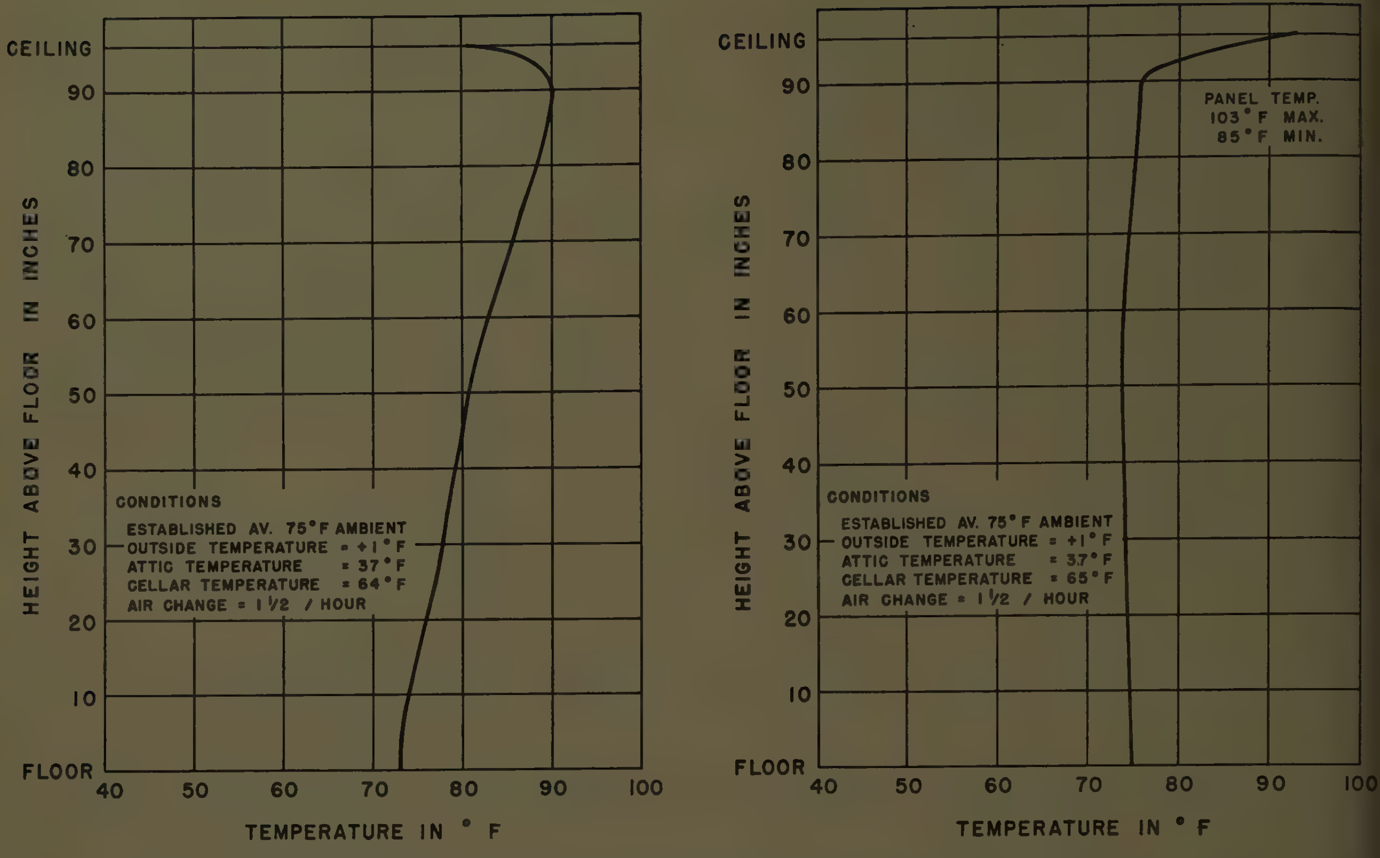


Figure 2. Results of a temperature gradient comparison test are shown (left) for a standard radiant heater located six inches from the floor, and (right) for a ceiling installation of electric radiant panel heating

specially developed sheet of aluminum. The unit is completely assembled with a termination block and a base section of a raceway. The raceway base has electric contact to both sides of the panel, and the ground circuit is through this section.

To accommodate the room module of residential structures, the panels are made in 46-inch, 58-inch, and 70-inch lengths, and the three sizes are all $17^1/_2$ inches wide. The standard panels are rated at 230 volts and have a wattage density of 21 watts per square foot.

Aside from the main advantage of increased comfort conditions, panel heating holds many other benefits for the user. A more dust-free air, cleanliness, fresh atmosphere, warm floors, more space availability, and architectural adaptability are obvious and will not be discussed in this article.

APPLICATION

For all general house-heating applications, the heated panel is located on the ceiling surface because of the higher radiant heating efficiency of this location. This panel design is not limited to a ceiling location, and it may be used on walls for specific applications such as thermally balancing large picture windows or other cold spots.

Panels may be mounted directly to the interior room surfaces. Sheetrock, plasterboard, or plywood provide excellent surfaces to which the panels may be attached. The back of the panel is equipped with a thermosetting adhesive resin which is in strip form. When the panel is to be mounted, the adhesive pattern is wetted with a suitable activator solution, and the panel pressed into position. The total time required to install one panel is approximately two minutes. After the panels are in place, the ceiling surface is painted or otherwise finished in a normal fashion.

Electrical power supply to the panel is effected by placing number-12 type-T stranded conductors in the channels of the connector block, which is assembled to the panel, and attaching the pressure cover with two screws. In each room or zone, if the room is large, the panels are connected in parallel with the branch circuit making connection to the panel circuit at one end of a panel group. The panel capacity in each room or zone is placed under the control of an individual low-voltage thermostat.

IMPROVING THE ECONOMICS OF ELECTRIC HEATING

Cost of operation for any heating system is based on the amount of heat which is lost during some specified time. Electric panel heating (or other forms of electric heating for that matter) should not be attempted unless the house is insulated. Areas having extremely mild weather might be considered an exception. An insulated structure not only has a much lower heat loss but is essential for optimum comfort conditions with a panel system. As pointed out before, no attempt is made to heat the air but rather to increase the mean radiant temperature of the room, and insulation works hand-in-hand with the panel system in accomplishing this condition.

A panel-heating system has lower operating cost than the conventional heating systems, and this is particularly

ue with a ceiling panel installation which takes advantage a larger radiation component. Since there is no longer y interest in heating the air as a means of establishing mfort conditions, operation can be at lower air tem-ratures. Thus, a reduction in the building transmission sses is effected and also the infiltration losses are reduced nce incoming air is heated to a lower temperature.

By using a very flexible heat source, such as a low mass ating panel along with a very sensitive control means, a nstant effective temperature is maintained. (See Figure) A convection system produces wide temperature riations between the "off" cycles, and the elimination these high-temperature blasts with their accompanying ershoots also can make for lower operating cost. Labora-ry experiments in which comparable effective tempera-res were created both by a conventional electric heater d also by means of a ceiling heating panel indicated a arked reduction in the power requirements for the panel ating.

IMPROVING THE LOAD CONDITION OF ELECTRIC HEATING

THE EFFECT of an electric house-heating load on the utility sometimes is overemphasized. It often is sumed that an electric heating load will be characterized high individual demands coming simultaneously. It is lieved that a high-cycling heat source having a very curate control means will develop considerable diversity ot only within a single residence having six or more cir-uits, but more so within a large group of homes so con-olled. The objective now is to obtain complete diversity st data on a large group of homes in one locality.

Proper application of electric heating is necessary if this ew field is to expand. Complete insulation results in wer heat loss and thus requires a lower connected load. n determining the heating capacity to be provided, a care-l analysis of the heat loss must first be determined. The ast procedure of making rule-of-thumb estimates, which ten result in excess capacity, cannot be tolerated. It is qually important that adequate capacity be provided. Vith the great flexibility of electric heating, there is no ecessity for excess capacity and connected loads must be ept as low as possible. This practice not only will help e power distribution problem but will make for a better ad factor. Panel heating holds still further possibilities r the power producer. Laboratory investigation in-cates that a sizable correction factor for the capacity quirement can be made with a ceiling panel system. Vhile confident of this reduction factor, it is preferable to ave a large number of field-test observations before neral use will be made of this factor.

Quite often, house heating is accused of being a purely asonal demand. This cannot be denied because its use curs only during winter months; however, as some ilities have recognized already, conceivably electric ouse heating can develop into the greatest application of omestic electricity. With the trend to more and more ectric servants in the home, a house-heating load may ell be the one which can be integrated with other house ads to fill the valleys of residential system loads of the future and thus improve the over-all load factor. It also should be pointed out that high heat requirements generally occur in the morning before other household demands.

Many ideas have been advanced for a method of restricting the coincident demand in an all-electric home. Some utilities presently use limiting equipment, timing equipment, modulating devices, carrier-current arrangements, and other devices, and some utilities are opposed to the use of such devices. It is believed that some such arrangement merits consideration, and several arrangements of load limiter devices now are being studied. Also, it is believed that a flexible source of heat utilizing a multiplicity of circuits which are operated by a very rapid cycling control will have very good diversity characteristics, and with a complementary saturation of other electric household devices will require no limiting arrangement; however, for those utilities which will benefit from a restricted load, limiting devices can be utilized.

INVESTIGATION OF ELECTRIC HEATING

IN APPROACHING the problems of improving the competitive position of electric heating, it was necessary to construct a Heating Research Laboratory in Bridgeport, Conn. This laboratory is made in three sections: one room is devoted to the weather-making machinery; a second part consists of a section of a typically constructed house located on the inside of a second building so that any type of weather can be simulated about the test unit; and in a third room are located all the power controls, instruments, and recording apparatus which record the weather conditions on the outside of the house as well as a complete cross check of conditions and changes occurring on the inside.

While it is not the intent to discuss the Heating Research Laboratory, which could itself be the subject of a paper, it is desired to mention briefly a method used in making comfort-condition observations. When the laboratory was first put into operation, live subjects were used to obtain the physiological responses under varied conditions. This procedure was abandoned and a copper man now is employed which is internally heated by electrical units. His condition can be set by modulating the power input to achieve any desired metabolism rate. The skin temperatures are tape-recorded through internally mounted specially fitted thermocouples, and his reactions to all changes of his environment are precise.

While many homes today are heated electrically, the increased use of electric energy for this purpose should be on a sound basis. The ever-increasing demand for electric heating should be tempered with sound engineering principles so that the mistake of poor installations which will result in increased costs not only to the consumer but also to the power producer will be avoided. The proper application of electric panel heating can benefit the consumer by providing optimum comfort conditions and at reduced operating costs. Panel heating can benefit the power producer by providing reduced connected loads, better diversity, and better load factors. Panel heating can improve the competitive position of electric space heating.

Synchronous Machine Reference Frames

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PRESENT-DAY economics indicate the practicability of long-distance a-c power transmission in many localities for distances greater than 300 miles. One of the important characteristics of such a transmission system is its steady-state stability limit. That is, at some particular steady-state load and system condition, when the synchronous machine is still able to supply more power across the line, the system nevertheless loses synchronism. This is interpreted physically to mean that the generator has no longer enough synchronizing torque to keep it in synchronism against small disturbances that continually arise.

It has been known that a voltage regulator attached to the field of the generator raises the steady-state stability limit to a higher value. The mechanism of this process has not been quite clear. No satisfactory physical theory of the small oscillations of a transmission system exists as yet and all attempts to explain physically the magnitudes of positive and negative damping and synchronizing torques of even such a simple system as a synchronous machine connected to an infinite bus have led only to very complicated expressions without any clear-cut physical picture.

It is one of our purposes to develop a consistent and fairly simple physical theory of hunting of a transmission system that is correct dynamically as well as practical. The purpose of the present article is a search for a new type of reference frame in which, during hunting, some fluxes behave as springs (positive T_S), other fluxes behave as masses (negative T_S), and in which the resistances behave as frictions (positive and negative T_D).

Electrodynamics is a young and still very little developed or understood subject. Even such a simple topic as the electromagnetic field of free space viewed from a reference frame in uniform translation leads to 4-dimensional relativity with all its mystic connotations and formulae. Although in a synchronous machine the velocities are small compared to the speed of light, and only magnetic fields, electric currents, and rotating magnetic and conducting media appear, nevertheless the reference frames and the media have different relative angular velocities. This difference in rotational speed between conductors, magnetic materials, and the observers themselves (the reference frames) leads to an electrodynamics that has no longer any parallel with conventional particle dynamics of moving material bodies. However, the parallelism still is maintained with modern differential geometry whose development was instigated by this very need of electrodynamics for a unified treatment, though in fields other than electric machinery. Nevertheless, any logical study of electric machinery must necessarily lead also to the same basic concepts that appear in the electrodynamics of moving elementary particles, namely, to multidimensional non-Riemannian spaces, to the Riemann-Christoffel curvature tensor, to nonholonomic reference frames, and to similar euphonious polysyllabic expressions that modern geometry has invented for use in electrodynamics.

Whether the electric power engineer likes it or not, he has no other choice. Only these strange-sounding creations of physicists and geometers fit the logic of the peculiar behavior of electric machines, and unfortunately even these creations are still very fragmentary and insufficient. Future progress in the theory of electric power utilization lies clearly along these very channels and the engineer necessarily must stumble through these same pathways either blindfolded or with an intelligent understanding of their peculiarities and pitfalls.

It has been argued that there are only two industrially important a-c rotating machines, the synchronous machine and the induction machine, and for that reason it is not worth while to build up an elaborate theory for their analysis. The flaw in the argument is that there are not two but only one type of a-c rotating machine. The difference between the various types of machines, and even the difference between the various theories of any one particular machine, may be reduced to the statement that it is all a question of point of view or, technically speaking, it is all a question of the reference frame assumed.

Having settled that the electrical engineer needs to write down the transient equation of only one machine consisting of one stationary and one rotating magnetic structure, his troubles are about to begin. Even forgetting the brushes, slip rings, the possible shunt and series connections, and simply concentrating on isolated windings in each axis, numerous possibilities arise in deciding the elementary question whether the reference frames should be connected rigidly to the magnetic structure or should be free of them. (The conducting windings themselves are connected rigidly to their respective magnetic structures.) In the complete article four such different possibilities are enumerated in the order of their increasing physical complexity and the reasons for their selection are discussed fully.

It is shown in this article that among the large number of possible reference frames of a synchronous machine there exists one frame, representable by an equivalent circuit, possessing the remarkable properties that for any complex transmission system the sum of its i^2r losses is equal to the damping torques and the sum of its i^2x powers is equal to the synchronizing torques of the various generators in the system.

Digest of paper **50-114**, "Classification of the Reference Frames of a Synchronous Machine," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Published in AIEE *Transactions*, volume 69, part II, 1950, pages 720–7.

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Damping and Synchronizing Torques

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THIS ARTICLE presents data on the variation of the synchronizing and damping torque coefficients of a ynchronous machine as affected by hunting frequency, re- tance and resistance of the system to which the machine connected, and characteristics of the rotor circuits, load, nd field excitations. The data are presented not only as eing of value in themselves but also to call attention to a raightforward method of calculation which has been vailable for a long time.[1]

The general case considered here is a machine connected an infinite bus through an impedance and oscillating with xed excitation about its operating angle. A few of the re- ılts obtained are shown in Figures 1 and 2. These figures ıow the damping and synchronizing torque coefficients, spectively, as a function of hunting frequency for three fferent machines operating at no load, and with various ne resistances.

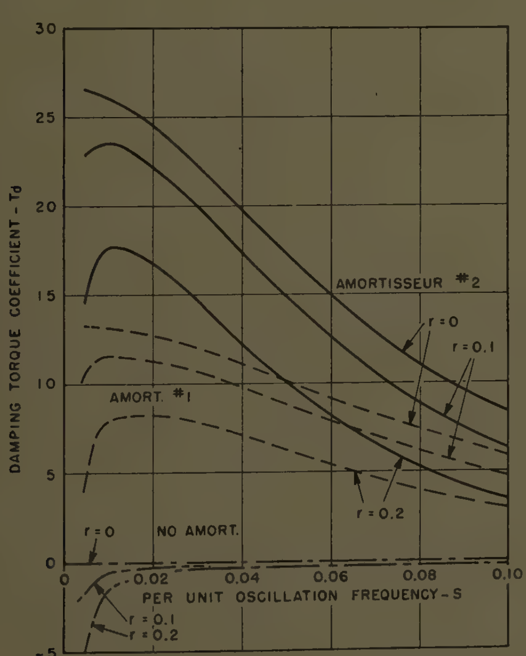
Some of the conclusions of the study are:

1. The equations given in reference 1 form a simple nd convenient means of calculating the components of unting torque with fixed excitation.

2. For a machine operating at no load and unit ex- tation:

(a) The synchronizing torque coefficient is not significantly affected by armature circuit resistance r in the range $r<0.2$, but is decreased somewhat for $r=0.4$ per unit.

(b) Practically all of the positive damping torque is produced by the quadrature-axis amortisseur circuits.



igure 1. **Damping torque coefficient of a synchronous machine a function of hunting frequency—for various line resistances and rotor circuits**

o Load ($\delta=0$); *Excitation Voltage* $E=1.0$; *Bus Voltage* $e=1.0$; *Line Reactance* $x_e=0$

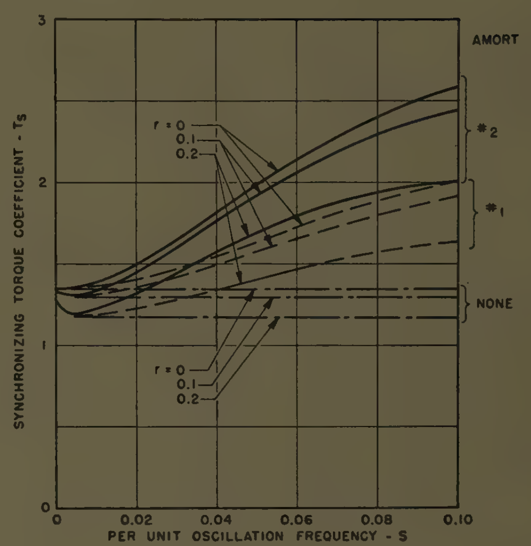


Figure 2. Synchronizing torque coefficient of a synchronous machine as a function of hunting frequency—for various line resistances and rotor circuit

No Load ($\delta=0$); *Excitation Voltage* $E=1.0$; *Bus Voltage* $e=1.0$; *Line Reactance* $x_e=0$

3. For a machine with an amortisseur equivalent to either of those treated in this article, the damping torque remains positive for any of the values of armature circuit resistance considered and independent of load angle.

4. For a machine with an amortisseur, the concept that stability (as far as hunting is concerned) improves with load is not a valid one. On the contrary, the damping torque is generally smaller under load than at no load, except at very small hunting frequencies.

5. With the combination of extremely high field excitation and armature circuit resistance and low bus voltage, it seems possible for the damping torque to become negative even with an effective amortisseur.

6. For a machine with an amortisseur, there is a considerable variation of synchronizing torque coefficient with hunting frequency in the range studied.

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Formed Power Transformer Cores

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Efficient and economical utilization of oriented cold-rolled steel requires that magnetic flux traverse the steel in the rolling direction; the effects of joints be reduced; and strains in the finished core be minimized. Reductions in core loss, exciting current, and noise level are being obtained in routine production units of Spirakore transformers using these principles

STEELS for magnetic circuits have been improved in many ways during the years of transformer improvement. Lower core loss, lower exciting current, improved mechanical properties, and nonaging characteristics are but a few of the improvements that have been made on the steel. However, until the introduction of highly oriented cold-rolled steel, essentially all distribution and power transformer cores were built by stacking rectangular, L-shaped, or E- and I-shaped laminations into a core structure.

In order to utilize better the improved magnetic characteristics of this new steel, a wound core was developed for distribution transformers.[1] Even though this type of core had good magnetic characteristics, it was limited to distribution transformer sizes. Weight, size, and mechanical requirements of cores used in power transformers prevented its use in these sizes. In order to obtain characteristics similar to the wound-core distribution transformer, a new type of precut, preformed, single-phase core for use in power transformers has been developed and put into production in sizes up to and including 3,333 kva. This article discusses the characteristics of oriented cold-rolled steel and the development of the "Spirakore" for use in power transformers.

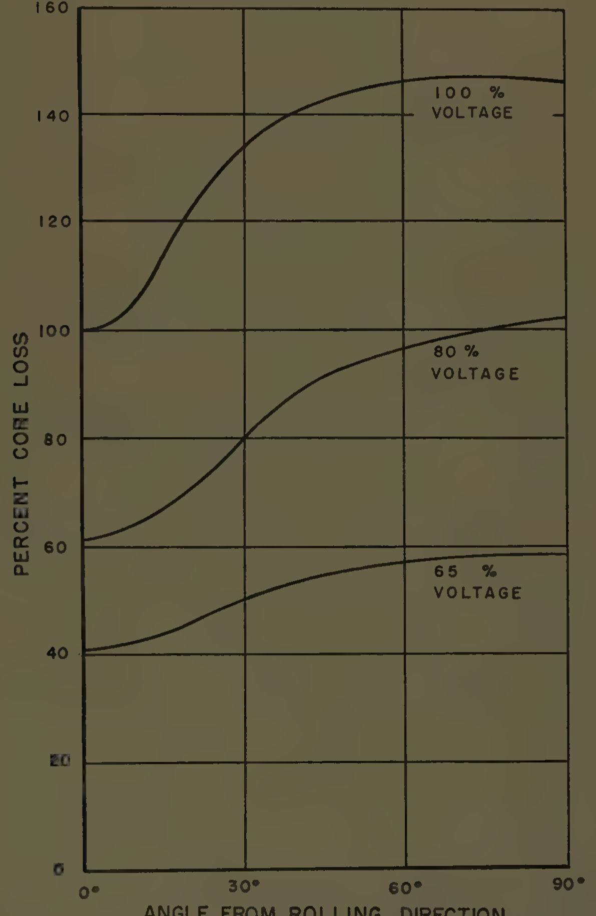

Figure 1. Variation of core loss with angle from rolling direction of steel

PROPERTIES OF MATERIAL

NONLINEARITY between flux density and magnetizing force is a characteristic of all steels used in power transformer cores. In addition, highly oriented cold-rolled steel has more important characteristics that must be considered if it is to be used efficiently in power transformer cores.

Directional Characteristics. Cold-rolled steel is produced in continuous strips or bandwidths, while hot-rolled material is produced in sheet form. With certain composition, working, and processing, highly directional magnetic properties may be obtained. A large proportion of the crystals are oriented so that an easy direction of magnetization is parallel to the rolling direction. In such material, when the flux passes through the lamination in a direction parallel to the direction of rolling, low core loss is obtained, and a low magnetizing force is required. If flux is caused to pass through such steel in directions other than one parallel to the rolling direction, core loss and magnetizing force are increased. The amounts which these quantities increase depend upon the flux density. Figure 1 illustrates the variation of core loss with the direction in which flux passes through such steel for three different flux densities. Figure 2 illustrates the variation of magnetizing force with the direction in which flux passes through the steel for three different flux densities.

Magnetic characteristic variations shown in Figures 1 and 2 show why it is important to use oriented cold-rolled steel in transformer cores so that flux passes through the steel in the direction of rolling. Not only may the lowest

Full text of paper 50-220, "Single-Phase Power Transformer Formed Cores," recom-mended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Published in AIEE *Transactions*, volume 69, part II, 1950, pages 1384–7.

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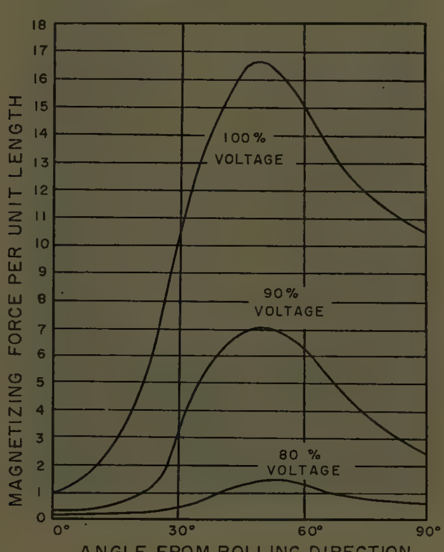
ssible core loss and exciting current be obtained, but inimum flux distortion will result as well.

Strain Effects. Oriented cold-rolled transformer core eel is much more sensitive to mechanical strain than is ot-rolled core steel. Both core loss and magnetizing force e increased as strain is increased. Because of this rain-loss relation, strain in the core structure must be nsidered seriously and minimized.

Core steel may be strained and formed into any desired ape before final anneal, but after anneal the steel should maintained in its annealed form for minimum core loss ıd magnetizing force. Therefore, in a core structure, re steel should be supported and clamped so that it is ept in the same form in which it was annealed.

GENERAL DESIGN OF CORE STRUCTURE

ASIDE FROM using oriented cold-rolled steel so that flux passes through it in a direction parallel to the rolling rection, other fundamental functions of the core must achieved. In designs using cylindrical windings, core oss section inside the winding circle should approach



gure 2. Variation magnetizing force r unit length with gle from rolling rection of steel

circle. Heat generated in the magnetic circuit must transmitted efficiently to the cooling liquid. Lifting, ipping, and short-circuit forces must be transmitted or ithstood by the core and clamp structure. These re- uirements are fulfilled by this type of core.

Core Cross Section. It has been shown that for a given ımber of widths of steel to be built into a core cross section pproaching a circle, certain widths and builds of packets ill give a maximum cross-sectional area.[1,2] Theoretical ptimum cross-section dimensions are determined first. hese dimensions may be modified slightly to permit use stocked steel widths on a line of core sizes and to allow r bolts, tie bars, and tie plates. These modifications do t reduce the cross-sectional area appreciably from the eoretical optimum area. Some form of bolting, bonding, tie-barring is required if a high space factor of iron is to obtained. Several widths of steel are used in any one re design, depending on the rating. The core has been divided into four quarters; quarters have been clamped in the center leg by insulated tie plates and tie bars, as shown in Figure 3. Outside legs are secured by angled plates which are a part of the clamp.

Not only does this arrangement give efficient utilization of the available iron space, but it gives step-backs in the

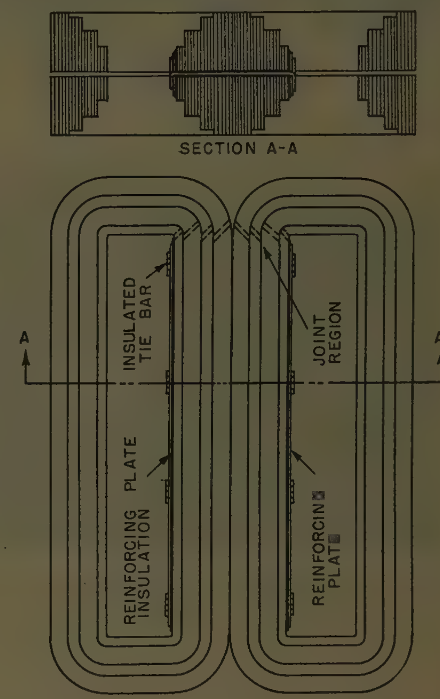


Figure 3. General arrangement of core quarter sections and cross sections

yokes at the tops and bottoms of the windows into which adjustable coil-support brackets may be fitted.

Core Form. To maintain the desirable magnetic characteristics of the wound-type cold-rolled steel core, the precut, preformed method was developed. This core, as applied in most Spirakore power transformers up to 3,333 kva, has one joint per lamination convolution. Joints are staggered in the joint region of Figure 3 so that a stepped joint having small overlap is obtained.

Starting with the lamination convolution forming one of the windows and progressing outward through the build of the core, lengths of the strips will increase linearly. Hence, if the core is developed horizontally into straight laminations, stacked with one end of the laminations at a vertical reference, the laminations would appear as a trapezoid with a rectangular end. Such laminations are progressively cut by an automatic indexing shear. As sheets leave the shear they are coated with a material which acts as a separator during annealing of the core and remains as an insulation coating to limit eddy currents between laminations during transformer operation.

As laminations leave the coating machine, they are stacked into a ring, then formed into the required rectangular-window shape. After anneal, a precut preformed core which will maintain its formed shape is obtained. Figure 4 shows one-fourth of a Spirakore power transformer at this stage of its processing and shows how the joints may be staggered and maintained in proper position in the

Figure 4. One-fourth of a single-phase Spirakore power transformer core

Figure 5. Formed core with coils on center leg and part of laminations reassembled around coils

magnetic circuit. All of the steel is utilized in the rolling direction, and no corner effects are introduced. Four such quarter cores are assembled into clamps.

Clamps. The clamping structure should be such that little, if any, strain on the core is introduced. Also, the core must be insulated from the clamps so that the core may be grounded at one point only. Multiple grounds, which would be obtained if the core were not insulated from the clamps, would result in partial- or total-turn short circuits on the core. Even though clamps should not strain the core, they should secure the core firmly and leave space for ducts for oil flow to cool the core.

For this type of core, a clamping structure has been designed which will cradle the core and permit lifting. Outer legs of the core are supported by the insulated outer vertical members of the clamping structure and insulated cross bars. The core is supported from the bottom by bottom cross bars, auxiliary cradling straps, and blocks. Coil supports on the bottom clamps support the windings, and lifting and short-circuit forces are sustained by the clamping structure, not by the core. It will be shown how adjustable top coil supports are attached to top clamps to maintain a tight coil stack.

Coil Assembly. Coils are placed on the center leg of the core by removing the top clamps, opening the joint, folding back the laminations, and then lowering the coil stacks into place. The laminations that are folded back must be supported when folded back so that the elastic limit of the core steel is not exceeded; exceeding the elastic limit would increase core loss and exciting magnetomotive force.

Laminations are put back into place until all of the laminations are back in the position in which they were annealed (see Figure 5). Bands around each quarter-core help maintain closed joints and reduce noise level. This method of core building and assembly gives close-fitting joints which are necessary for low core loss, low exciting current, and low noise level.

Top clamps, top clamp insulation, cross bars, clamping bolts, and the adjustable coil supports then are added. Blocking immediately over the joint region further reinforces the joint for tightness. The core and coil assembly as shown in Figure 6 is then ready for cabling, treating, and tanking. The pierced tab extending from the left side of the core in Figure 6 is the core grounding strap. This strap is not bolted to the clamp until the core

Figure 6. Formed core with coils completely clamped and ready for cabling

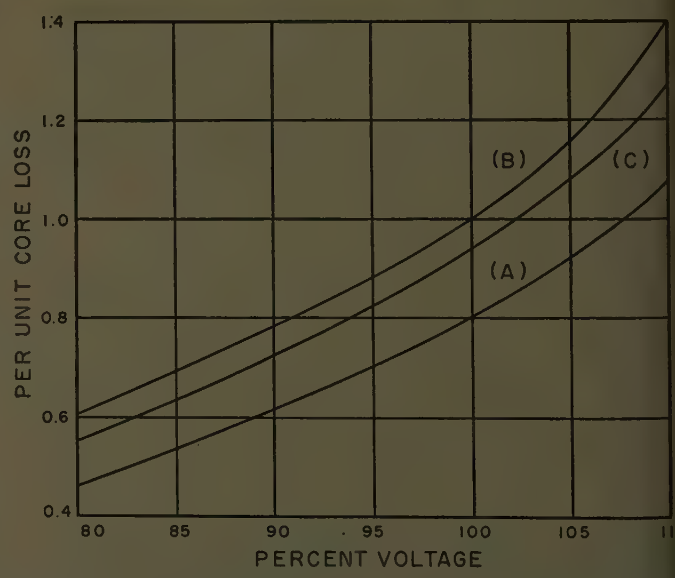
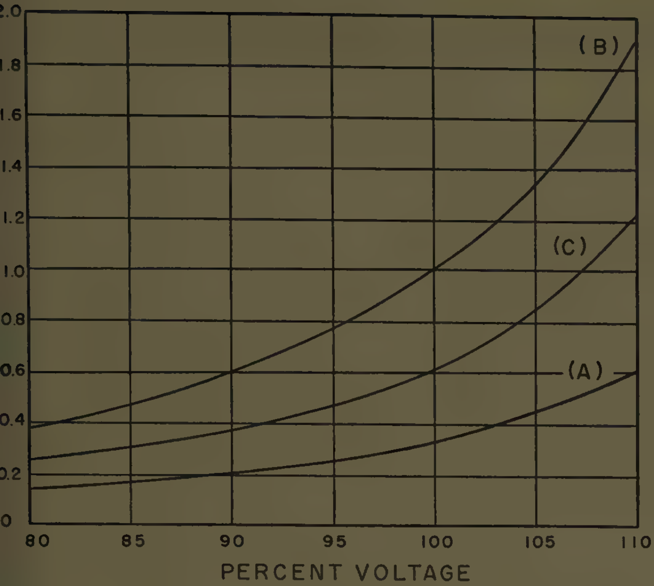


Figure 7. Curves showing variation of core loss with per cen[t] voltage (A) formed core; (B) plate core with lapped joints; (C) plate core with mitered joints



gure 8. Curves showing variation of exciting current with r cent voltage (A) formed core; (B) plate core with lapped joints; (C) plate core with mitered joints

d coil structure has been treated so that the core may be sted for grounds when it is ready for final tanking.

CHARACTERISTICS OF TRANSFORMER

FFECTIVE UTILIZATION of oriented cold-rolled steel in the formed core is best measured by the charac-ristics of the completed transformer built on this type of re. In Figures 7 and 8 are curves which show 60-cycle re loss and exciting current as functions of per cent ted voltage for a given transformer rating built on three fferent cold-rolled steel core designs. Curve *A* is for a sign using the formed core as described in this article. urve *B* is for a design using rectangular plate laminations and conventional lapped joints. Curve *C* is for a design using plate laminations and mitered joints.

The improvement in core characteristics resulting from the Spirakore construction is quite obvious. The core loss is reduced to 80 per cent and the exciting current to 35 per cent of the values obtained with a core using plate laminations and lapped joints. The improvement from the use of mitered joints is appreciable but not as great as from the use of Spirakore construction.

Several factors account for these improvements in core loss and exciting current.

1. Flux passes through the core steel and joints in a direction parallel to the rolling direction of the steel.
2. Joint regions are a small part of the total magnetic circuit, thus introduce very little reluctance in the magnetic circuit.
3. Strain effects on the core are reduced by cradling clamps around the core and not loading the core with coil weights and supporting forces.
4. Joints are closed and maintained tight by the clamping structure.
5. The core is annealed in its final form so that no assembly, piercing, forming, or shearing strains remain in the core.

Although the 3-leg 4-section single-phase core has been described in this article, similar 2-leg 2-section designs have been made and built. These designs may be built with either two or four joints per convolution, depending upon the particular design requirements.

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New Plastic Developed with Improved Flotation Qualities

A new expanded plastic for use in making life rafts, life ng buoys, and other flotation equipment was announced cently by the United States Rubber Company. The oduct is honeycombed with millions of tiny nonconnecting lls which make it extremely light. It is not affected by n or salt water, and will stay afloat indefinitely. Other plications for the new plastic are for sun helmets and mmercial fishing floats.

Life rafts of the material can be molded in one piece. me are large enough to support 60 men. Because they ve a solid noncommunicative structure, the rafts will ay afloat after strafing. Little or no maintenance is quired.

In addition to its flotation qualities, the new product is thermal insulator as well. Its most important applications in this field have been those that require insulating material which can supply structural strength. Because the material has little moisture absorption, its thermal insulating properties remain adequate for a long time.

The new product is said to have dielectric properties also. Since exposure to water and weather will not affect its inherent transmission properties, it will give consistent and uniform protection to the equipment which is housed within it.

It is manufactured in flat sheets which can be formed by conventional thermoplastic forming techniques or it can be molded into shape. Its density can be varied for the application desired from 5 pounds per cubic foot to 35 pounds per cubic foot. Standard sheets available are 46 inches by 70 inches in 1/4, 1/2, 3/4, and 1-inch thicknesses.

A Reluctance Motor Design Method

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ASSOCIATE AIEE

METHODS OF DESIGN, described previously for the reluctance motor, present a design procedure which results in three major steps. The three steps are: (1) choose trial dimensions and windings, (2) calculate the motor constants, and (3) calculate the performance of the trial design. Previous articles have described the method of choosing the optimum dimensions, calculating the constants and the performance. No method has been described which allows the designer to choose the correct number of turns and the wire size for a given or specified performance.

This article provides a means by which the correct turns and wire size may be chosen for either a specified load point or a maximum torque. The method used is termed design by synthesis. This method permits the designer to set up the constants of the motor in terms of ratios whereby it is possible then to derive equations in terms of the number of stator turns and the performance point or condition. This approach to design was thoroughly described by Lloyd[1] and it is the basis for this article.

The vector diagram for the reluctance synchronous motor is shown in Figure 1. This diagram applies to one phase of the polyphase reluctance synchronous motor and is based on the 2-reaction theory.

From the vector diagram, the equivalent circuit shown in Figure 2 is derived. From the equivalent circuit, it is possible to derive the equations necessary to determine the power developed, the full load current, the power factor, the power input, and the efficiency. The power output is determined from the internal voltage of the machine and the internal voltage is a function of the applied voltage. This means that the primary impedance drop is in terms of the amount of load on the motor and enters into the output equation. If C_r represents the voltage correction due to the stator resistance and C_x represents the voltage correction due to stator reactance, then the term C_rC_x represents the correction applied to the terminal voltage which corrects for the stator impedance drop. The term C_rC_x can be determined before the winding is selected, thus enabling the designer to determine more accurately the correct number of turns and wire size. The term C_rC_x also can be determined after the correct winding has been selected, which permits the designer to predict more accurately the desired performance. The accuracy and the ease with which the system can be handled rests entirely with the term C_rC_x.

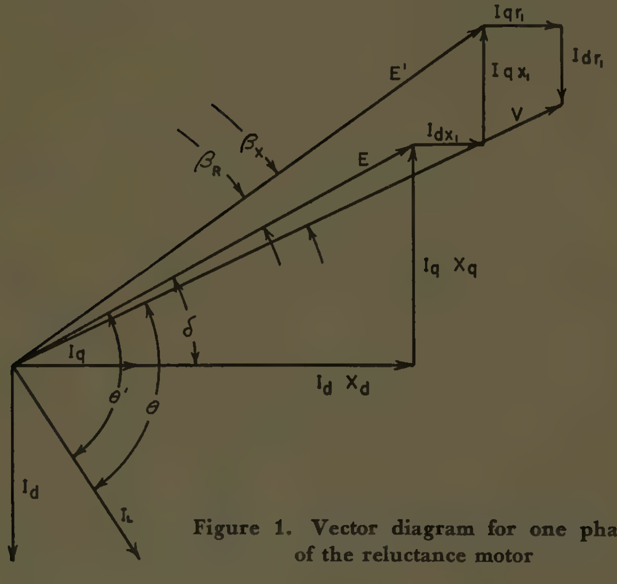

Figure 1. Vector diagram for one phase of the reluctance motor

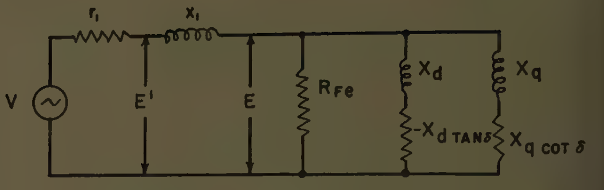

Figure 2. Equivalent circuit derived from the vector diagram

As an indication of the accuracy to be expected, Table I contrasts the performance obtained from calculation and test.

Table I. Reluctance Synchronous Motor Performance Data

Full Load Values	Calculated	Tested
Shaft output, watts	188	187
Total input, watts	286	288
Line current, amperes	1.81	1.79
Efficiency, per cent	65.6	64.8
Power factor	0.415	0.422
No Load Values		
Current, amperes	1.55	1.54
Power input, watts	84.7	80
Power factor	0.143	0.136
Maximum torque, ounce feet	31.6	33.6

It is believed that this system fills a gap in the process of designing polyphase reluctance synchronous motors. The process presented allows the designer to choose directly the number of required turns and wire size, thus eliminating the trial and error method of design.

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Metal Wall Thickness Measurement from One Side by the Ultrasonic Method

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This article discusses the principles of metal wall thickness measurement from one side and an instrument for making such measurements. The selection of quartz crystal and range, accuracy, and limitations of the method are covered.

THE NEED for an instrument which will measure wall metal thickness ondestructively when only ne side is accessible is widepread. Practical applications clude measurement of tanks, ip hulls, pipes and tubes, nd many types of pressure vessels where it is required to etermine the extent of metal thinning due to erosion or orrosion. Several different methods have been used. hese include measurement of potential drop, measureent of back-scattered radiation from a radioactive source, ectromagnetic methods, ultrasonic pulse methods, and e ultrasonic resonance method. The ultrasonic resnance method to be described in this paper is the most cent and, although it does have limitations, it is the ethod most widely used at the present time because of s inherent simplicity, accuracy, reliability, and wide nge. In addition to thickness measurements, instruents operating on the ultrasonic resonance principle also ave proved useful for flaw detection applications.

PRINCIPLES

THE ULTRASONIC resonance principle of thickness measurement depends upon two fundamental characristics of sound waves. First, they travel through metal a velocity that is a function of its density and of its astic constants. This velocity is not appreciably inuenced by wide variations in temperature. For the comonly used steels, the sound velocity is essentially indeendent of the chemical composition, previous heat eatment, internal stresses, and the electrical or magnetic roperties.

The relationship is expressed by

$$=\left[\frac{E}{\rho}\left(\frac{1-M}{(1-M)(1-2M)}\right)\right]^{1/2}$$

hen V is the velocity of longitudinal waves in centimeters er second; E is the Young's modulus in dynes per square ntimeter; ρ is the density in grams per cubic centimeter; d M is Poisson's ratio.

In the second place, sound waves are reflected by intercial surfaces separating two materials such as metal and ater that have different acoustical impedances. Standg waves can be set up within the wall of a pipe, or within a metal plate, just as standing waves are set up within the air column of an organ pipe, as shown in Figure 1. The frequency of the standing waves depends upon the thickness of the material and the velocity of sound in the material, just as the frequency of the organ pipe depends upon its length and the velocity of sound in air.

The fundamental frequency at which thickness resonance will occur is given by the relation

$$f_1=V/2t$$

where f_1 is the frequency in cycles per second; V is the velocity of sound in the material in inches per second; and t is the thickness in inches. This relation is correct for the case where the work piece has a higher impedance than that of the materials on its opposite faces—and this is the practical case.

Thickness resonance occurs also at all harmonics of the fundamental frequency such as

$$f_2=2f_1,\ f_3=3f_1\ldots f_n=nf_1$$

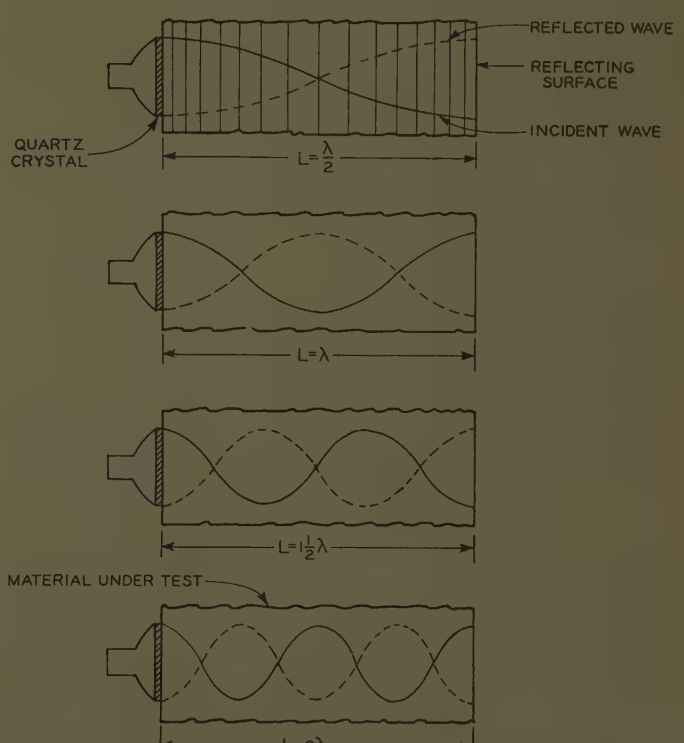

Figure 1. Representative standing-wave patterns of ultrasonic vibrations in material

ll text of a conference paper presented at the AIEE Winter General Meeting, uary 22–26, 1951, New York, N. Y. Recommended by the AIEE Committee on ectronics.

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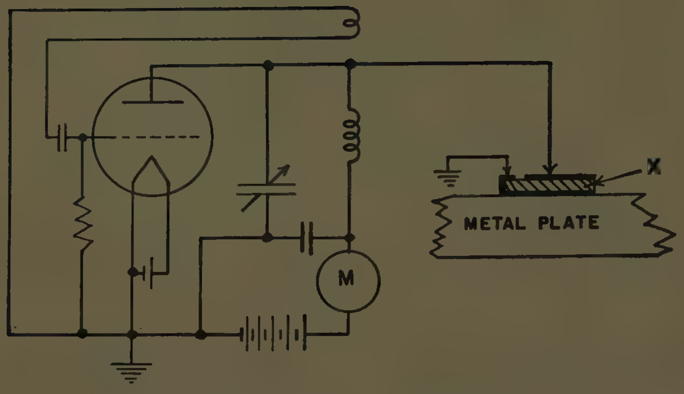


Figure 2. Basic circuit for a variable-frequency ultrasonic thickness tester

The frequency difference between two adjacent harmonics is numerically equal to the fundamental frequency. When the fundamental frequency is known, the thickness can then be determined from the equation $t = V/2f_1$.

When two adjacent harmonic frequencies are known, the equation used is

$$t = \frac{V}{2(f_n - f_{n-1})}$$

The instrument under discussion performs two functions—the transmission of sound waves of known frequencies into the material and the detection of the presence of standing waves.[1] A basic circuit, shown in Figure 2, comprises a variable-frequency self-excited oscillator that generates an alternating voltage which is applied to an X-cut quartz crystal. When the crystal is held against the material to be tested, with a film of oil or other suitable coupling fluid between the crystal and the work, an ultrasonic wave is transmitted into the material. If the oscillator is tuned to a frequency that is an integral multiple of the fundamental frequency of the wave in the thickness of the material, there will be a sharp increase in the amplitude of the vibration in the part of the wall directly under the crystal. This is a resonant condition and because of the internal damping in the material there will be an increase in the energy dissipated. The effect on the oscillator is the same as adding a resistive component across the inductance-capacitance circuit and a sharp increase in the plate current of the oscillator will result.

The increase in oscillator plate current due to thickness resonance may exceed 100 per cent under ideal conditions. Under many practical conditions the change in plate current at resonance may be only a fraction of one per cent. Increased sensitivity over the circuit shown in Figure 2 is then necessary and is obtained by frequency-modulating the electronic oscillator over a small frequency increment. The result will be pulses of current in the oscillator plate circuit when the average oscillator frequency is tuned to the frequency at which a thickness resonance occurs. These current pulses are produced at an audio-frequency rate and are amplified by conventional methods. A schematic circuit diagram used for a portable battery-operated type of instrument is shown in Figure 3. Thickness resonance is indicated by an audible tone in the head-phones and increased deflection of an output meter.

The frequency at which resonance occurs is read on a calibrated scale and converted to thickness by use of a concentric conversion scale provided on the instrument panel. This scale is adjustable to the sound velocity in the type of metal to be measured. In the case of harmonic resonance indications, the fundamental resonance is equal to the frequency difference between two adjacent harmonic frequencies. By using harmonic resonance indications it is practical to use a 2- or 3-to-1 frequency range for measurements over a thickness range of 100-to-1, or more.

Other types of instruments,[2] designed to frequency-modulate over a 2-to-1 frequency range, apply the amplified output to the vertical plates of a cathode-ray oscilloscope to provide direct reading indications.

QUARTZ CRYSTALS

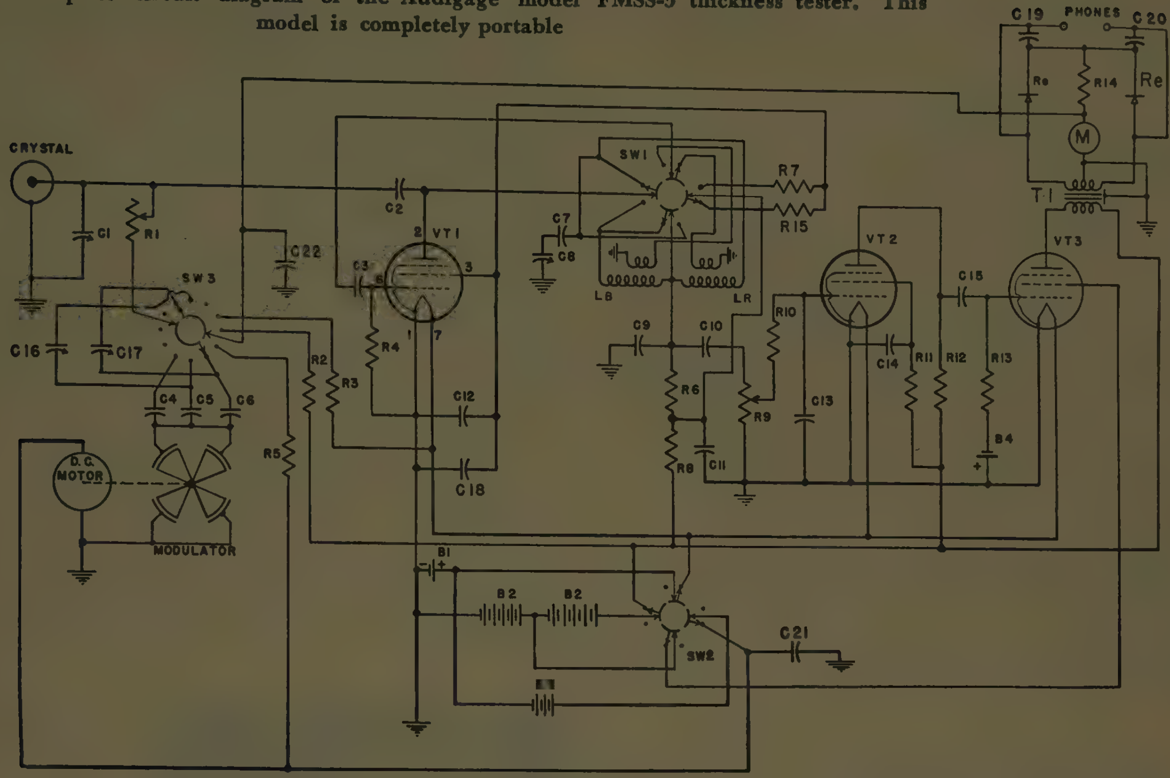
The X-cut quartz crystal which is used to convert electrical to mechanical energy is probably the most important component of an ultrasonic resonance thickness gauge. Its electrical frequency is the same as the mechanical frequency. In such equipment it is generally necessary that the quartz crystal be driven over a 2-to-1 frequency range, or more. The highest frequency at which the crystal is driven should be below the natural frequency of the crystal itself. If a crystal is driven at its natural frequency, there will be a resonance indication which is similar to the indication obtained when the crystal is vibrating a section of metal at a thickness resonance frequency.

In addition to the resonance indication obtained at the natural frequency of the crystal, there are also many spurious resonances throughout the entire frequency range at which the crystal must be driven. The spurious resonances in an undamped quartz crystal may have a much greater effect on a sensitive oscillator circuit than the metal thickness resonances obtained on many practical applications. The crystal is therefore cemented to a suitable plastic which substantially damps out spurious

Table I. Effect of Various Curved Crystals on Signal Strength
Glycerin-Aerosol Solution Used as Coupling Medium

Material Tested	Crystal Type	Gauge Thickness, Inches	Sensitivity	Remarks
4 1/2-inch outside diameter steel pipe, slightly scaled, 0.556-inch wall	Flat, 1 1/2 square inch area	0.550	20	Use of proper curved crystal increased strength and sharpness of signals
	4 1/2-inch curved, 1 1/2 square inch area	0.550	50	
5-inch outside diameter heater tube with 3/8-inch coke deposit on inside 0.53-inch wall	Flat, 1 1/2 square inch area	0.530	25	
2 3/8-inch outside diameter steel pipe, scaled and corroded, 0.17-inch wall	Flat, 1 1/2 square inch area	...	0	No clear resonance indications obtainable
	2 3/8-inch curved, 1 1/2 square inch area	0.175	10	Use of curved crystal permitted measurement of this pipe
6 3/16-inch outside diameter steel tube, 1 31/32-inch wall	Flat, 1 1/2 square inch area	1.930	5	
	6 5/8 inch curved, 1 1/2 square inch area	1.930	50	Use of proper curved crystal increased sensitivity 10 times

gure 3. **Complete circuit diagram of the Audigage model FMSS-5 thickness tester. This model is completely portable**



rystal resonances but does not reduce crystal sensitivity xcessively.

In testing hundreds of X-cut crystals, all having essenally the same physical dimensions, the quality of the rystals from the standpoint of spurious resonance response as been found to vary as much as 100-to-1. Crystals hich have excessively large spurious resonance peaks can ot be damped satisfactorily for applications where high ensitivity settings of the electronic equipment must be sed.

The intensity and sharpness of thickness resonance ndications obtained from a metal thickness will depend to large extent upon the area of contact between the crystal nd the metal and upon the ultrasonic frequency which is sed. In practice, it has been found that a crystal with diameter of $1^3/_8$ inches is satisfactory for use at frequencies om about one to two megacycles. Smaller diameter rystals can be used at higher frequencies.

Flat crystals are used on surfaces with a radius of curvaure of over six inches without much loss in sensitivity ompared to the same crystal on a flat surface, providing suitable viscous coupling liquid is used between the rystal and the work. Crystals also are cut to fit practically ny desired curvature and result in substantially better erformance for applications on small pipes. Table I hows data obtained for flat and curved crystals on different ipe sizes.

THICKNESS RANGE AND ACCURACY

OW FREQUENCIES (long wavelengths) are suitable for thick specimens and rough surfaces. High frequencies ermit the use of smaller crystals and the measurement of hin materials, provided the work piece is sufficiently nooth and homogeneous.

The minimum thickness of material which can be measured depends upon the ultrasonic frequency which it is possible to use. On materials such as steel, aluminum, and glass, with smooth parallel surfaces, it is possible to use ultrasonic frequencies of 20 megacycles or higher, and measure thicknesses of 0.005 inch, or less. However, many materials will absorb the acoustic energy very rapidly at such frequencies with the result that there will be no thickness resonance indications. Certain types of cast iron, for example, can be measured at frequencies below one megacycle but no detectable resonance effect can be observed at higher frequencies. In general, most metal thicknesses of 1/16 inch or more can be measured. By using harmonic resonance indications it is sometimes possible to measure thicknesses of several feet. It is common practice to measure heavy-walled pressure vessels with wall thicknesses of several inches by using harmonic resonances.

Accuracies within one per cent generally can be obtained when it is possible to use the fundamental or the lower harmonic indications. On materials of 1/2 inch or more, where it is necessary to use higher harmonics, accuracies of 2 to 3 per cent can be realized.

LIMITATIONS

FACTORS WHICH sometimes make it impossible to use the ultrasonic resonance method are excessive thickness variations in the material within the area contacted by the crystal; damping due to dense, closely adherent scale on the opposite surface of the material to be measured; and the type of material.

Thickness variations in the material within the area contacted by the crystal are usually due to severe corrosion which creates deep pits in one or both sides of a metal

Table II. Effect of Coupling Medium on Signal Strength
Flat Crystal Detector Head, 7½-Square-Inch Area

Material Tested	Coupling Medium	Gauge Thickness, Inches	Sensitivity	Remarks
Cold rolled steel, 0.308 inch thick, smooth surfaces	Grease	0.310	Over 100	Lowest indication, at 0.77 megacycle, hardly detectable with grease. Indication is sharp and distinct with Dow Silicone stopcock grease
	Silicone Grease	0.305	100	
0.308 inch steel with hard and closely adherent scale on the reflecting surface	Grease	0.310	0.3	Meter indications practically unusable. Distinct audible signals at 1.9 and 1.53 megacycles. Low frequency indications not audible
	Glycerin-Aerosol*	0.305	4.6	Signals considerably stronger than with grease
Steel ship plate, 0.560 inch thick, scale and slight pitting on reflecting surface	Grease	0.544	65	Sufficiently strong indications with grease
Steel ship plate, deep pitting on reflecting surface, maximum 0.550 inch, minimum 0.470 inch	Grease	0.500	1	Very weak signal
	Glycerin-Aerosol	0.495	10	Sensitivity increased approximately ten times by using glycerin

Note: Solution consisting of one gram of "Aerosol" per quart of glycerin. Aerosol serves as a wetting agent.

plate. If only one surface is severely pitted, and if this surface is accessible for measurements, a hand-operated power grinder can be used to prepare a suitable surface and there will be no difficulty in obtaining readings. When the inaccessible surface is pitted, the ultrasonic energy is scattered at the reflecting surface and the intensity of thickness resonance indications will decrease. Excessively deep pitting will make it impossible to detect resonance indications.[3] The maximum peak-to-valley depth of pitting which can be tolerated depends on the thickness to be measured and the frequency used. In general, when the peak-to-valley depth of pitting exceeds 20 per cent of the total thickness or if it exceeds one-half a wavelength (about 1/8 inch of steel at one megacycle) it will be impossible to detect resonance indications. A nonuniform thickness such as a wedge will have a similar effect.

Dense, closely adherent scale on the opposite (inaccessible) surface will have a strong weakening effect on the intensity of resonance indications although the scale will not be measured. In the measurement of ship hulls, for example, there is usually considerable pitting and a heavy scale on both sides. By using a power chipper to remove scale on one side and a grinder to provide a relatively smooth surface, it has been possible to use ultrasonic resonance type instruments to measure the remaining metal wall thickness. Table II indicates the effect scale and pitting will have on sensitivity for different coupling media. Sensitivity is defined as the ratio of resonance indications to the inherent background level.

Nearly all materials, including concrete, plastics, and so forth, can be measured if sufficiently low ultrasonic frequencies can be used. However, since it is necessary to use very large crystals at the lower frequencies, the cost of crystals or the problem of obtaining suitable contact over a large area may make it impractical to measure materials with poor transmission of the higher ultrasonic frequencies. Frequencies above one megacycle are usually most suitable for applications on metals and glass.

Figure 4. The complete portable Audigage flaw detector

Figure 5. Measuring the thickness of pipes with a portable ultrasonic thickness gauge

In general, most of the ultrasonic energy will be reflected at the interface between a metal and a liquid, since liquids have generally lower impedances than metals. It is therefore possible to measure the wall thickness of tubes and tanks without any error due to a liquid in contact with the opposite surface. An exception which has been encountered was on tubes used in a mercury boiler. The combination of mercury together with a wetting agent made it impossible to obtain a reading for the wall thickness of such tubes unless the mercury was removed, since mercury is also a high-impedance material.

FLAW DETECTION

SINCE ULTRASONIC waves are reflected at any discontinuity, it is possible to apply the same principles

sed for thickness measurement to certain flaw detection pplications. One type of commercial equipment which used to detect cracks in rails within the joint bar area is own in Figure 4. The complete equipment, including lf-contained power supply, weighs only 11 pounds and e condition of the rail is indicated by the audible tone roduced in headphones. In this equipment, the fre- uency is modulated over a range which includes many esonance peaks and results in an audible tone with a requency which is proportional to the distance from the p of the rail to the first discontinuity. Other applica- ons include the detection of laminar flaws in metal lates and hydrogen blisters in pressure vessels. The output of the instrument may be applied to any cathode-ray oscilloscope to provide a visual, rather than an audible, indication, when desirable.

Figure 5 shows a portable thickness tester in use. After preparing the test surface, the operator applies the crystal while making adjustments on the instrument.

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Electrical Essay

Three-Phase Network

The engineer from the land of pure electrical constants as showing me his collection of odd networks. He took ne of them from the shelf and sketched its connection iagram as shown in Figure 1. The network includes hree air-core transformers of unity turn ratio, without

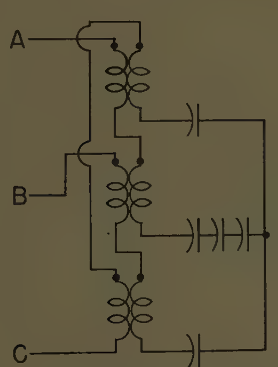

Figure 1. Sketch of connection diagram of the 3-phase network

osses, and with coils having the same value of self-induct- nce and mutual inductance. Coils of two transformers re connected in series with a capacitor to form each leg" of a 3-phase star-connected network. At a specified requency each winding has a reactance jX, the mutual eactance of each pair of windings in a transformer is X, the reactance of the capacitor in the reference phase $-j3X$, and the reactance of the remaining two capacitors $-jX$ each.

What is the property of this network that gives it a lace in the engineer's collection?

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Answer to Previous Essay

A 4-Point Network. The following is the author's answer to his previously published essay (*June '51, p 540*).

Determination of mutual voltage drops. Select any three points from the original network (for example, *A*, *B*, and *C*) and assume the original network to be replaced by a delta (see Figure 1) of impedances between the three points such that the impedance between any pair of points on the equivalent delta is the same as the known impedance

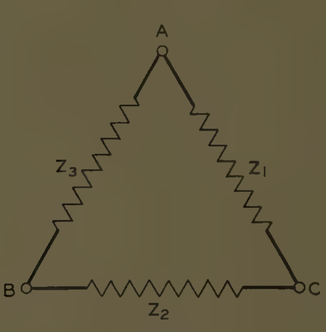

Figure 1

of the original network between the corresponding pair of points.

$$Z_{AC}=\frac{Z_1(Z_2+Z_3)}{Z_1+Z_2+Z_3}$$

$$Z_{AB}=\frac{Z_3(Z_1+Z_2)}{Z_1+Z_2+Z_3}$$

$$Z_{BC}=\frac{Z_2(Z_1+Z_3)}{Z_1+Z_2+Z_3}$$

The mutual voltage drop between *AB* and *AC* is defined as the voltage from *C* to *A* when one ampere enters the network at *B* and leaves the network at *A*, and by the reciprocal theorem this voltage is equal to the voltage from

B to A when one ampere enters the network at C and leaves the network at A.

Assume that one ampere enters the network at B and leaves at A:

$$E_{AB} = Z_{AB}$$

$$E_{AC} = \frac{Z_1}{Z_1+Z_2}\,(Z_{AB}) = \frac{Z_1Z_3(Z_1+Z_2)}{(Z_1+Z_2)(Z_1+Z_2+Z_3)} = \frac{Z_1Z_3}{Z_1+Z_2+Z_3}$$

From the equations shown for Z_{AC}, Z_{AB}, and Z_{BC} it will be found by trial that

$$\frac{Z_1Z_3}{Z_1+Z_2+Z_3} = {}^1/_2(Z_{AC}+Z_{AB}-Z_{BC})$$

Therefore

$$E_{AC} = {}^1/_2(Z_{AC}+Z_{AB}-Z_{BC})$$

Thus the mutual voltage drop between a pair of impedances meeting at a point equals half the sum of the

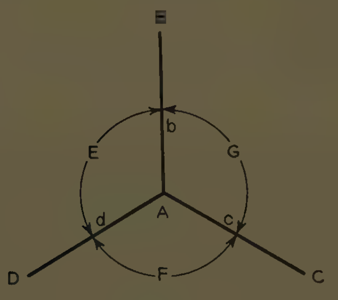

Figure 2

network impedance across each of these impedances minus half the network impedance across the open delta formed by the two impedances meeting at the point.

Determination of branch impedances in the 4-point network. Select one point from the original 4-point network and consider only the impedances connecting to this point (for example, point A and the connecting impedances z_{AB}, z_{AC}, and z_{AD}). The impedances connecting to point A are drawn 120 degrees apart in Figure 2 for purposes of symmetry.

NOMENCLATURE

Z_{AB}, Z_{AC}... are terminal impedances between these points as measured from the original network

z_{AB}, z_{AC}... are branch impedances to be determined in answer to the problem

I_{Bb} is the current through b when one ampere enters the network at B and leaves the network at A

I_{Db} is the current through b when one ampere enters the network at D and leaves the network at A

Similar meanings assigned to I_{Cb}, I_{Bd}, I_{Dd}, I_{Cd}, I_{Bc}, I_{Dc}, and I_{Cc}. Capital letter subscript indicates the point where one ampere enters the network and lower case subscript the impedance through which the current flows.

B is the voltage at B with respect to A when one ampere enters the network at B and leaves the network at A. $B = Z_{AB}$

C is the voltage at C with respect to A when one ampere enters the network at C and leaves the network at A. $C = Z_{AC}$

D is the voltage at D with respect to A when one ampere enters the network at D and leaves the network at A. $D = Z_{AD}$

E is the mutual voltage between b and d which equals the voltage at B with respect to A when one ampere enters the network at D and leaves the network at A. This is also the voltage at D with respect to A when one ampere enters the network at B and leaves at A. $E = {}^1/_2(Z_{AB}+Z_{AD}-Z_{BD})$

F is the mutual voltage between c and d. $F = {}^1/_2(Z_{AD}+Z_{AC}-Z_{CD})$

G is the mutual voltage between b and c. $G = {}^1/_2(Z_{AB}+Z_{AC}-Z_{BC})$

SOLUTION

$$I_{Bb}(z_{AB}) = B \qquad (1)$$
$$I_{Db}(z_{AB}) = E \qquad (2)$$
$$I_{Cb}(z_{AB}) = G \qquad (3)$$

Dividing equation 1 by equation 2 and cross multiplying gives equation 4. Also dividing equation 1 by equation 3 and cross multiplying gives equation 5. This operation eliminates the unknown impedance z_{AB} and gives two equations in three unknown currents.

$$B(I_{Db}) = E(I_{Bb}) \qquad (4)$$
$$B(I_{Cb}) = G(I_{Bb}) \qquad (5)$$

Repeating the above steps for the voltage drops in impedances z_{AD} and z_{AC} results in equations 6, 7, 8, and 9.

$$D(I_{Bd}) = E(I_{Dd}) \qquad (6)$$
$$D(I_{Cd}) = F(I_{Dd}) \qquad (7)$$
$$C(I_{Bc}) = G(I_{Cc}) \qquad (8)$$
$$C(I_{Dc}) = F(I_{Cc}) \qquad (9)$$

Equations 4 through 9 are six linear equations involving nine unknown currents. Three more current equations may be written based upon the fact that in all cases one ampere is assumed to enter the network at some point and to leave the network at A. This means that the sum of the currents flowing toward A must equal one in each case, and thus equations 10, 11, and 12 may be written.

$$I_{Bb}+I_{Bd}+I_{Bc} = 1 \qquad (10)$$
$$I_{Db}+I_{Dd}+I_{Dc} = 1 \qquad (11)$$
$$I_{Cb}+I_{Cd}+I_{Cc} = 1 \qquad (12)$$

Solving the foregoing nine linear equations in nine unknown currents for one of the currents gives

$$I_{Bb} = \frac{BCE+BDG-BCD-BF(E+G-F)}{CEE+DGG+BFF-BCD-2EFG} \qquad (13)$$

Repeating equation 1

$$I_{Bb}(z_{AB}) = B \qquad (1)$$

$$z_{AB} = B/I_{Bb} = \frac{CEE+DGG+BFF-BCD-2EFG}{CE+DG-CD-F(E+G-F)} \qquad (14)$$

Equation 14 is an expression for one of the unknown impedances in terms of B, C, D, E, F, and G which are related to the given impedances in the nomenclature. B, C, and D are directly equal to some of the given impedances while E, F, and G are each equal to half the sum of two of the given impedances minus half of another of the given impedances. Equation 14 is a preferable form of answer to substituting the given impedances in it as it is shorter and is so symmetrically related to the diagram that expressions for the other unknown impedances may be written by inspection.

The foregoing solution is a general one which may be applied to similar problems of any number of points.

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Sensitive Relays in Process Control

R. T. PIERCE

Sensitive relays often can be used in process control where conventional controllers are impractical or too expensive. This article outlines some of the design factors that must be considered when using these relays and gives some typical circuits.

SENSITIVE RELAYS offer a method of control in processing that is finding many applications where conventional controllers or recorder-controllers may be too complicated or too expensive. These relays operate on the permanent-magnet moving coil principle, and are capable of contacting on small values of microamperes or millivolts.

Sensitive relays are made with two basic types of contacts, nonmagnetic and magnetic. When any relay makes contact, it must exert enough pressure to break through the surface resistance of the contact material. Therefore, the nonmagnetic contact relay requires enough energy to overcome this surface resistance.

The magnetic contact relay has a permanent magnet for the stationary contact and a magnetic rider on the movable contact arm. The energy required is only that necessary to deflect the movement until the rider on the movable contact arm is in the magnetic field of the stationary contact. At that time, the contacts snap together with a force that may be as much as 2,000 times the operating torque of the relay. This force is much greater when the two magnetic pieces are suitably alloyed to serve as the contacts.

However, the magnetic contacts have to be reset by some outside force. This may be accomplished manually or by a solenoid reset. The manual reset generally is used if corrective action on the part of an operator is desirable and the resetting occurs after normal operating conditions are re-established. The solenoid reset is built into the relay and the circuit to the solenoid may be completed by contacts on a secondary relay that is in the chain of operation.

In the following discussion the control of temperature by using thermocouples or resistance bulbs will be used as an example, but the same factors would apply if some other low-energy converter were used.

Nonmagnetic Contact Relays (see Figure 1). Due to contact resistance, the limit in movable coil sensitivity is 7.5 microamperes or about one millivolt at a coil resistance of one ohm. Also, the secondary circuit handled by the contacts must be suitably engineered to limit arcing. On most of these relays the contacts are rated 200 milliamperes at six volts direct current noninductive load.

When changes in the controlled quantity occur at a fairly rapid rate, a nonmagnetic contact type of relay may

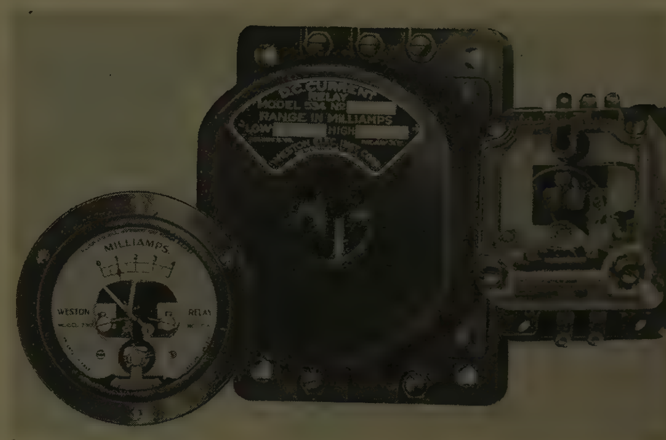

Figure 1. Three types of nonmagnetic relays

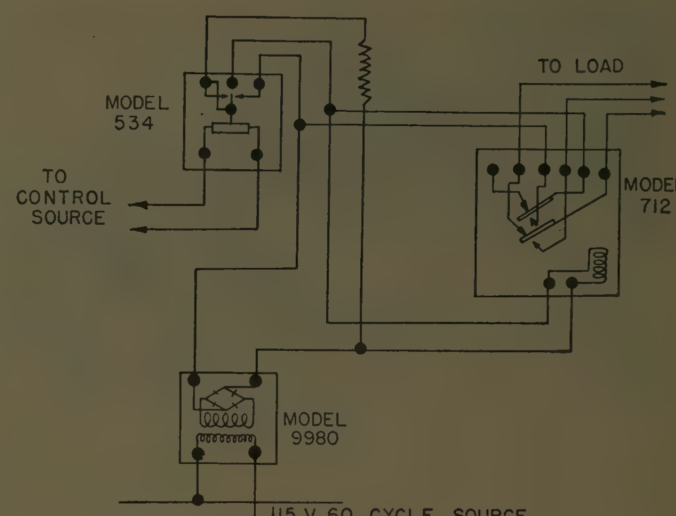

Figure 2. This circuit uses a nonmagnetic relay and requires no reset mechanism

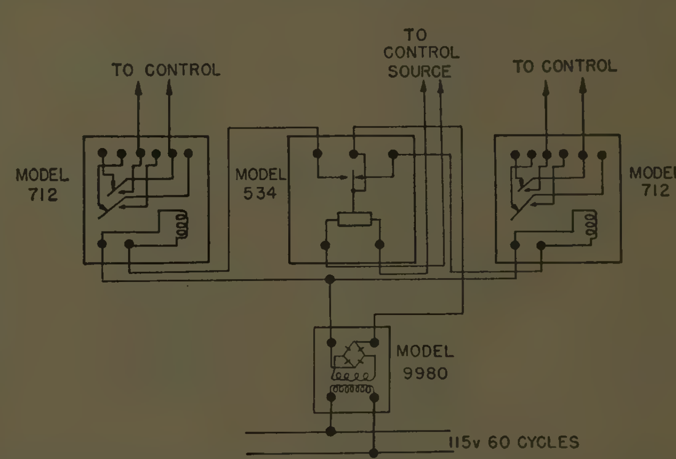

Figure 3. This sensitive relay circuit is useful if changes in the controlled quantity are fairly rapid

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be used. But when these changes are slow, arcing may occur before positive contact is made.

If it is difficult to work out methods of resetting the magnetic contact, the circuit shown in Figure 2 will enable a nonmagnetic contact relay to be used. In this circuit a pair of contacts on the power relay is used in parallel with a pair of the sensitive relay contacts so that when the power relay closes it locks itself in. When the sensitive relay makes contact on the other side, the operating coil on the power relay is short-circuited through a suitable resistance and opens. This reduces arcing and provides reliable operation for long periods of time.

Figure 3 shows a typical wiring diagram for application where the changes in the controlled quantity are fairly rapid. If on and off control from one set of contacts on the sensitive relay is desired, one power relay may be omitted.

Magnetic contact relays. Magnetic contact relays, Figure 4, have a number of advantages over the nonmagnetic contact relays, provided a method of resetting can be worked out. Also, some of these relays have a calibrated scale and methods of adjusting to contact at various operating values.

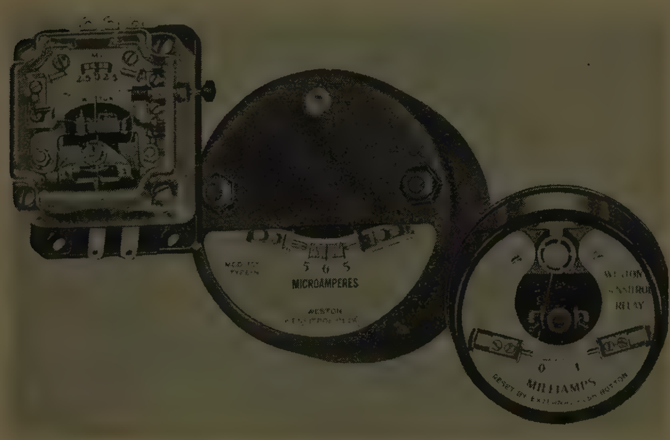


Figure 4. Some typical magnetic contact relays

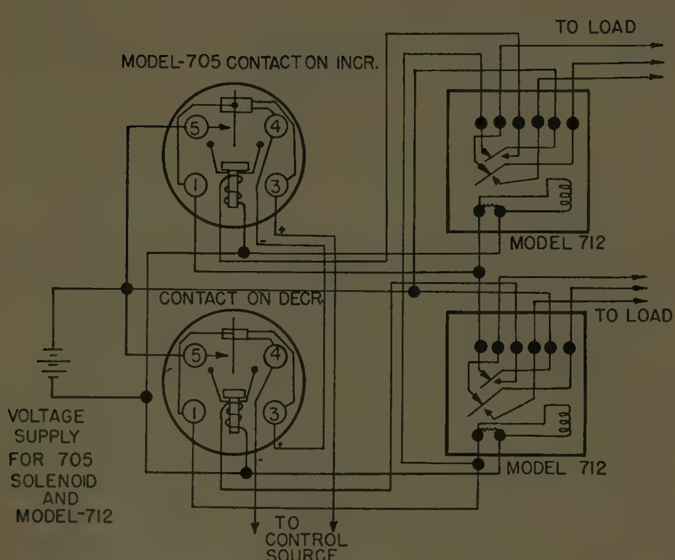


Figure 5. Temperature control circuit using two magnetic contact relays, one to increase, the other to decrease temperature

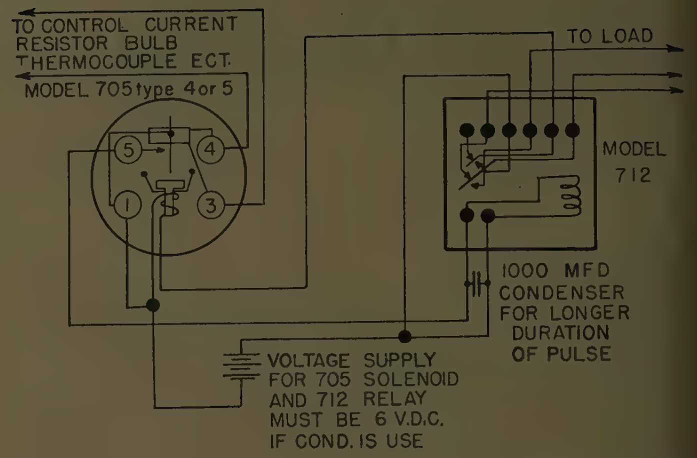


Figure 6. A pulsing-type control using a magnetic contact relay

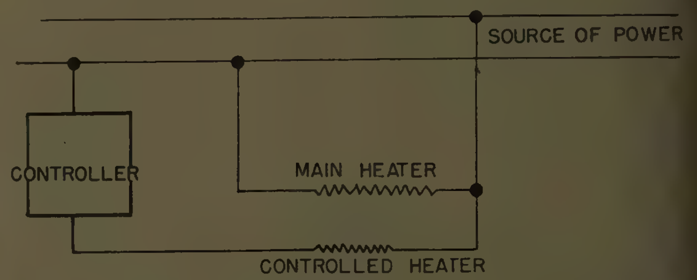


Figure 7. The smaller controlled heater enables a close control of temperature

The most sensitive relay will make contact on 0.5 microampere or on one millivolt with a coil resistance of 2,000 ohms. Other of the relays illustrated in Figure 4 make contact at five microamperes or on 2.5 millivolts with a coil resistance of 500 ohms. The contacts will handle five watts at 115 volts, 60 cycles.

Figure 5 shows two magnetic contact relays, one for contacting on increasing temperature and one for contacting on decreasing temperature. Each relay is equipped with a solenoid reset and has a power relay. The power relay contacts reset one sensitive relay when the other operates.

Figure 6 shows a pulsing type of control using one magnetic contact relay and one power relay. The magnetic contact relay closes when heat is required and closes the power relay. Contacts on the power relay reset the magnetic contact relay through its solenoid. However, when the power relay closes it supplies a pulse of energy to the heating source and then the contacts open. If the pulse of energy to the heating source has not raised the temperature sufficiently, the contacts will close again. This will continue at slower intervals until the temperature is correct.

This method is capable of very close control. Care should be taken to control as small a portion of the load as possible to keep the load on the power relay contacts low. This may be accomplished by connecting the main heater across the source and controlling a smaller heater to maintain proper temperature, as shown in Figure 7.

These circuits are typical control applications using sensitive relays. Many variations might be used for special control characteristics such as time delay and slow action or fast action in the basic response of the sensitive relay.

Magnetrons for Dielectric Heating

R. B. NELSON

High power magnetrons are used at the ultra-high frequencies for fast dielectric heating. One such tube, generating 5 kw at 915 megacycles, and associated control circuits are described.

MICROWAVE TUBE developments several years ago reached the ıge where kilowatts of ›wer were available at freıencies of 10^9 to 10^{10} cycles. ıe question quickly arose, Why cannot all dielectric heating which is difficult or ıpossible at low frequency be done easily at these microave frequencies?" Fundamental to dielectric heating the relationship

$$=2\pi f E^2 \epsilon'' \times 0.0885 \times 10^{-12} \quad (1)$$

ıere P=power in watts per cubic centimeter converted heat in the dielectric, f=frequency of alternating ectric field, E=rms field strength in volts per centimeter, ıd ϵ''=loss factor of the dielectric.

If it is desired to increase the rate of heating a given electric material, the field strength or the frequency ay be increased. The field strength is easy to control, ıt it can be increased only to the limit imposed by arcing tween the electrodes and the work. The field strength which arcing occurs varies tremendously with different nds of materials. For a box of raisins—high-dielectric-nstant lumps touching at small points—there is a conntration of field at the contact points which causes cing and local burning at low electrode voltage.

CHOICE OF FREQUENCY

T IS SEEN from equation 1 that the rate of heating at constant voltage is proportional to frequency if the loss ctor does not change. In most materials, the loss factor tually rises with frequency in the useful ranges. This unds like an unmitigated blessing: a sufficiently high equency can be used to heat any material as fast as is sired with a voltage safely below the breakdown point. ıere are, however, limits on usable frequencies imposed economic and physical factors.

In the microwave region, it has been found extremely fficult to shield dielectric-heating equipment to reduce diation below the Federal Communications Commission's CC) allowable maximum. For example, a series of ts was made of radiation from a resonant-cavity box. ıe cavity contained a dinner and was fed with 4 kw of wer at 1,040 megacycles. The following average raated field strengths were measured:

Method of Closing Cavity	Radiated Field Strength (Microvolts per Meter at 1 Mile)
lio-frequency choke filter	1,000
ger contacts	300
ke filter plus surrounding metal cabinet	400
lered cover	Small

These measurements, made by Dr. H. W. Anderson of the General Electric Electronics Laboratory, are not presented as accurate data. Their order of magnitude demonstrates, however, that shielding is impractical in the microwave region. Heating apparatus is essentially confined to the frequency bands assigned for this service where large amounts of stray radiation are permitted. These bands are as follows:

Center Frequency, Megacycles	Deviation Allowance, Megacycles	Quarter Wavelength in Air, Inches
915	± 25	3.22
2,450	± 50	1.21
5,850	± 75	0.50
10,600	±100	0.28
18,000	±150	0.16

At 915 megacycles, a rugged magnetron oscillator, to be described in this article, is available to give 5 kw output. Experimental magnetrons have been built to produce 50 kw in this frequency range.

At 2,450 megacycles, magnetrons are available from the Raytheon Manufacturing Company giving up to 2 kw output. At higher frequencies, tubes suitable for industrial use have not yet been put on the market. They can be made if a demand for them develops.

Most of the materials to be heated with microwaves are relatively low-loss dielectrics. This means that in the passage of an electromagnetic wave through the material, only a small part of the energy in the wave is absorbed per wavelength of travel. If it is desired to dissipate all the energy in the wave in a piece of dielectric no more than a few wavelengths long, the wave must be reflected back and forth through it many times. Interference of these reflected waves sets up a standing-wave field pattern with maxima and minima of field strength separated by one-quarter wavelength.

The standing-wave pattern imposes definite restrictions on the size of objects which may be heated uniformly at a given frequency. Consider the case of a cylindrical resonant cavity excited with the electric field parallel to the axis.

The electric field strength is given by

$$E = E_{\max} J_0(6.28\, r/\lambda) \quad (2)$$

where $E_{\max}$=maximum field (on the axis), r=radial dis-

Essential text of a conference paper, "Tubes for Dielectric Heating at 915 Megacycles," recommended by the AIEE Committee on Electronics and presented at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951.

R. B. Nelson, formerly with the General Electric Company, is now with Litton Industries, San Carlos, Calif.

tance from the axis, and λ=wavelength in the material with which the resonator is filled.

In Figure 1 is plotted the variation in E^2 derived from this equation. The rate of heating, proportional to E^2, is greater than 90 per cent of its maximum value inside a radius of 0.07λ.

In a practical case, such as heating a plastic preform, the dielectric load is placed only in the center of the cavity where the field is high and uniform. If the diameter of the cavity is adjusted for resonance, with a coaxial cylinder of dielectric, the field in the dielectric will be exactly the same as the field in a smaller cavity completely filled with dielectric.

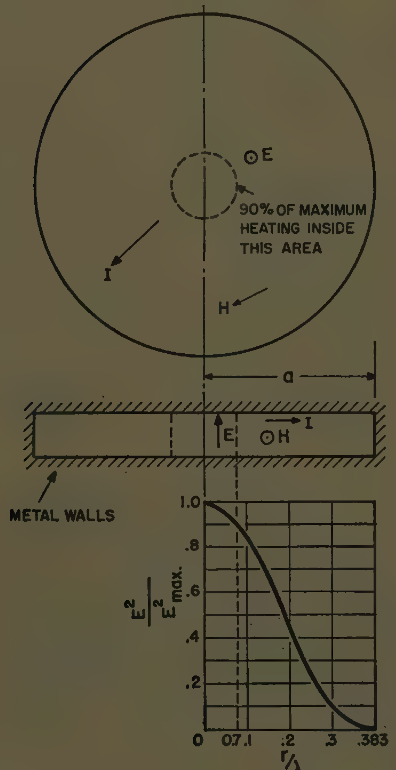


Figure 1. Electric field distribution in cylindrical resonator. Rate of dielectric heating at any point is proportional to E^2

For a plastic material of dielectric constant 4.0, heated with 915-megacycle waves, the wavelength in the material is given by the equation

$$\lambda=\frac{\lambda_0}{\sqrt{\epsilon'}}=\frac{12.9}{\sqrt{4.0}}=6.45 \text{ inches} \tag{3}$$

where λ_0=wavelength in free space in inches, and ϵ'=real part of dielectric constant.

If the plastic cylinder has a diameter d such that its outside surface is heated 90 per cent as much as its center

$$d=2\times0.07\times6.45 \text{ inches}=0.9 \text{ inch} \tag{4}$$

is the maximum diameter permitted.

This example illustrates the role of standing-wave patterns in selecting frequencies. Another effect becomes important for very high-loss materials. Here the electromagnetic wave may lose its energy so rapidly in its first passage into the material that at the center of the load the fields are too weak to produce enough heat. For example, consider roast beef with a dielectric constant of 28 and a loss factor $\epsilon''=5.6$ at 915 megacycles. The attenuation constant α for the fields of a wave is given by

$$\alpha=\frac{\pi}{\lambda_0}\,\frac{\epsilon''}{\sqrt{\epsilon'}} \tag{5}$$

The power density in the wave

$$E^2=E_0^2e^{-2\alpha} \tag{6}$$

If the effective depth of penetration p of the wave is defined as that depth at which the power density has fallen to $1/\sqrt{e}$ or 0.61 of its initial surface value

$$p=\frac{1}{4\alpha}=\frac{\lambda_0\sqrt{\epsilon'}}{4\pi\epsilon''}=\frac{\lambda}{4\pi\epsilon''} \tag{7}$$

In roast beef

p=0.97 inch effective penetration at 915 megacycles.

Figure 2. A 5-kw magnetron tube. The tube on the right is completely sectioned, except the cathode

These examples indicate how, for any type of load, consideration of the wavelength in the material in relation to the size of the piece leads to the choice of frequency. Present applications use the 2,450-megacycle and the 915-megacycle bands, and it appears that these will remain the most important in the microwave region, even when

Table I. Specifications of *Z1492* Magnetron

Electrical		Mechanical		Maximum Ratings	
Filament-pure tungsten		Radio-frequency output, 3¹/₈-inch coaxial		D-c plate voltage	5,00
Filament voltage	10.5	Anode water flow, gallons per minute	2	Plate dissipation, watts	3,00
Filament current, maximum, amperes	53.5	Maximum outgoing water temperature, degrees centigrade	70	Plate input, watts	7,50
Filament starting current, maximum, amperes	80.0	Mounting position—axis vertical		D-c plate current, amperes	
Frequency, nominal, megacycles	915			Standing wave ratio (voltage)	3-to-
Magnetic field, gauss	1,400				

›es eventually become available for operation in the
:her frequency bands.

THE 915-MEGACYCLE 5-KW MAGNETRON

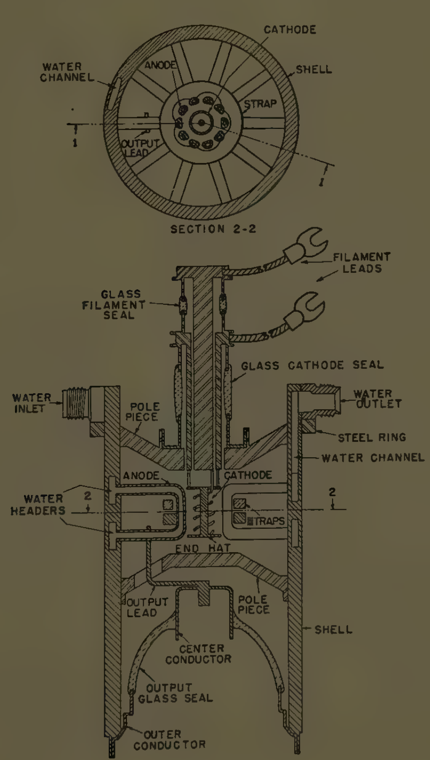
ɴ THE General Electric Company, microwave heating investigations and developments have been con-
ıtrated at 915 megacycles. Tube development, which
d to come first, was started in the General Electric
search Laboratory in 1945 with a 5-kw magnetron
cillator, the *RN48*, operating at 1,040 megacycles. The
tory model of this tube, changed to 915 megacycles
ıen the FCC assigned a frequency band, has the develop-
ental designation type *Z1492*.

Specifications and operating conditions of the *Z1492*-
ıgnetron are listed in Table I.

CONSTRUCTION

A COMPLETE magnetron, and a similar one cut open to show the interior, are shown in Figure 2.

Construction of the 5-kw magnetron is shown in the
ction drawing, Figure 3. The filament is a helix of pure
ngsten wire of 0.400-inch diameter. Surrounding it are
ı anodes on a 0.687-inch diameter, formed by U-shaped
ɔps of 3/16-inch copper tubing through which the cooling
ıter flows. This method of removing heat from the
odes gives good dissipating ability and practically
minates frequency drift from thermal expansion of the
ode structure. The ten resonant circuits of the oscillator
e formed by the anode pipes themselves and the copper
be shell connecting them at their outer ends. At their
ıer ends, the anode pipes are connected alternately by
pper straps into two sets of five anodes. The purpose
these straps is to increase the frequency separation be-
een the resonant modes of the anode structure so that
e oscillation always will take place in the desired mode



**ɡure 3. Con-
uction details of
:w 915-mega-
ycle magnetron**

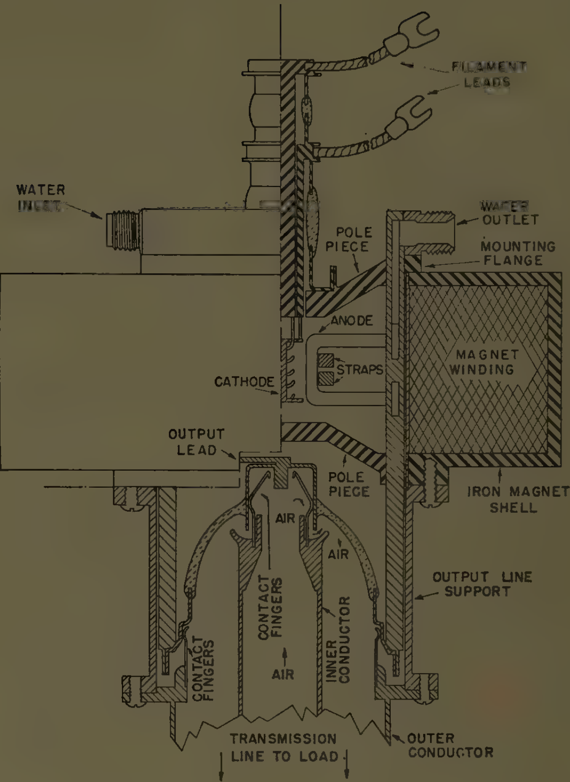


Figure 4. Magnetron mounting and connections. The tube slides into the magnet, bottom end first, and simultaneously makes contact with the output transmission line

with alternate anodes 180 degrees out of phase. The resonant circuits would be quite loosely coupled without the straps, with the resulting resonant frequencies differing by a few per cent. In the strapped structure, resonances of a laboratory tube were at 1,063 megacycles, 2,110 megacycles, 3,040 megacycles, 3,750 megacycles, and so forth. This extreme mode separation is not necessary, but it has proved very desirable in dielectric heating. Where the impedance presented by the load to the oscillator may change greatly, it is well to have insurance against oscillations jumping to another mode.

Returning to Figure 3, coupling of the anode tank circuits to the load is provided by a copper strap connected to one leg of one anode pipe and leading through the glass output seal to an external coaxial line. The point of attachment to the anode pipe is determined to give the proper loading of the oscillator when the transmission line is reflectionless.

The tube is mounted by sliding it inside its solenoidal electromagnet. As shown in Figure 4, the magnet has an iron shell which carries the flux. Jumping a short gap formed by the copper-tube shell, the flux enters the iron pole pieces inside the tube and provides the magnetic field parallel to the axis of the anode and cathode. As the tube is plugged into its magnet, its output end makes contact with the inner and outer conductors of the transmission line. Air is blown in through the inner conductor to cool the glass seal, which itself undergoes dielectric heating.

Operating characteristics of a magnetron are best shown by two sets of curves. Figure 5 is a performance chart

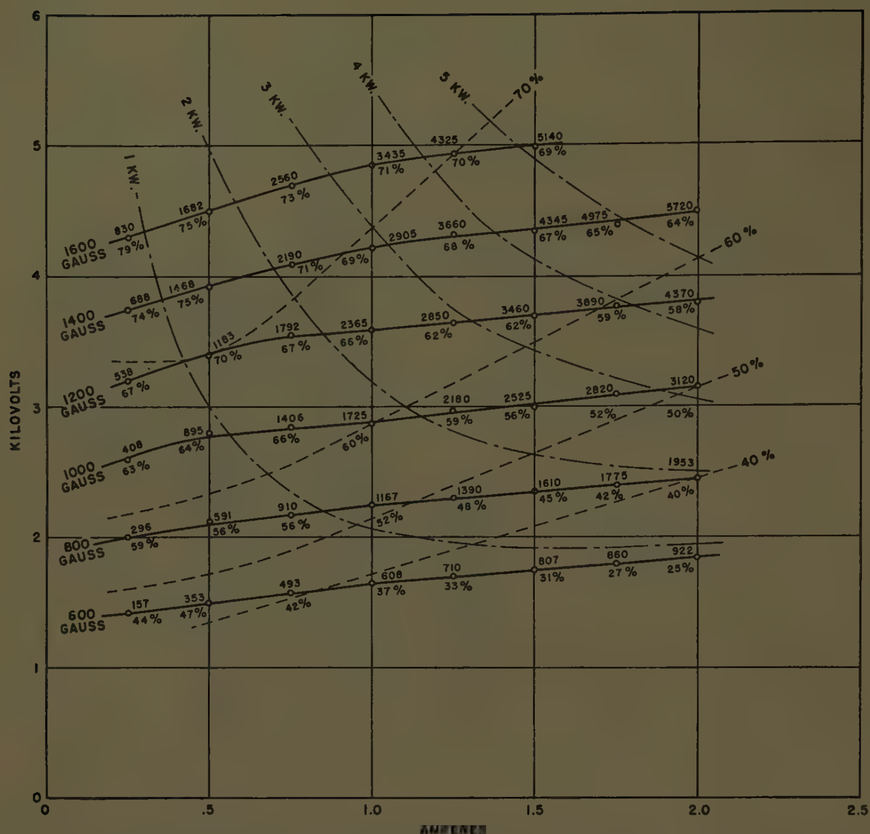
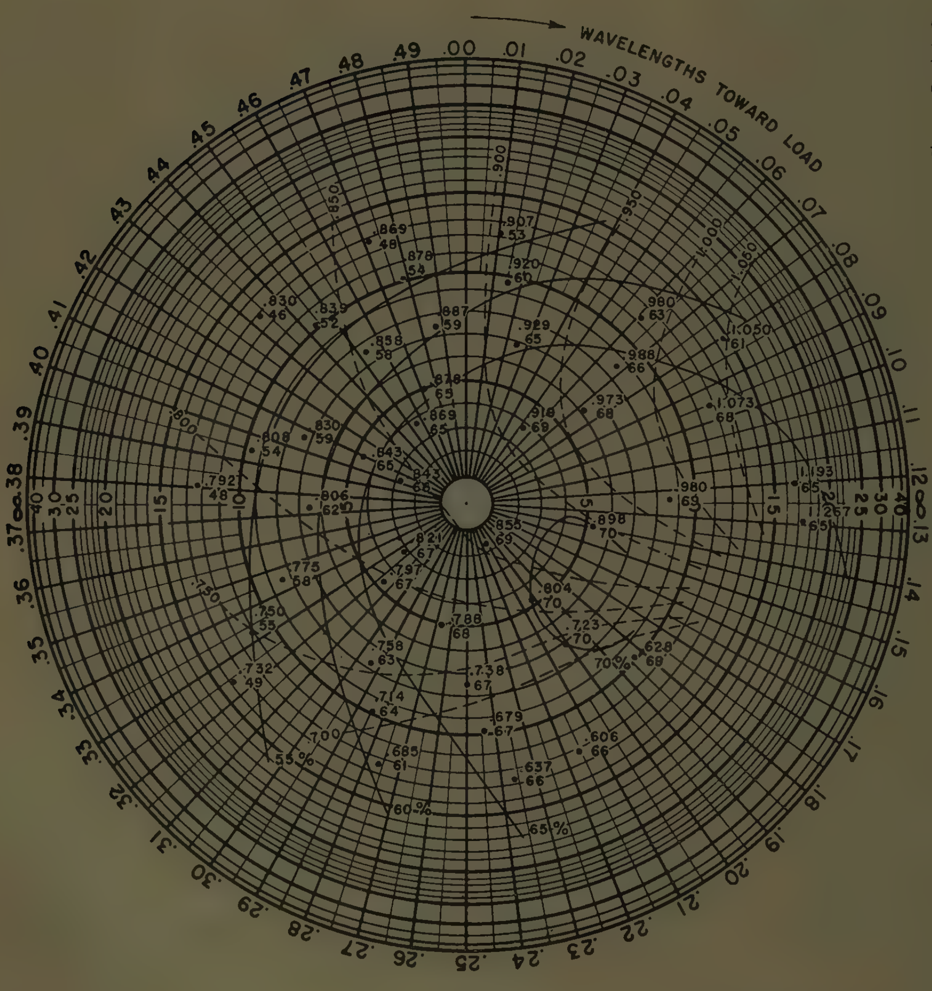


Figure 5. Performance chart of 5-kw magnetron. Dotted lines are contours of plate-circuit efficiency



where contours of magnetic field, output power, and efficiency are plotted on co-ordinates of plate voltage and current. These data are taken with the transmission line matched to the load.

Figure 6 is a Rieke diagram where, for standard conditions of plate current and magnetic field, the efficiency and wavelength are plotted on co-ordinates of reflection coefficient of the load for waves going down the transmission line.

ASSOCIATED CIRCUITS

Electromagnet control. The magnetron is essentially a diode, operated for convenience with its anode grounded. The plate power supply is between cathode and ground. It has been found advantageous to return the low-voltage end of this supply to ground through the electromagnet, so the magnet is effectively in series with the plate current of the magnetron. The reason for this may be seen by examination of Figure 5. If the magnetic field is constant, a small change in plate voltage produces a large change in current and output power. The dotted curve in Figure 7 shows this relation. Line-voltage fluctuations can cause serious output variations.

When the plate current flows through the electromagnet, an increase in plate voltage causes increased current to flow, raising the magnetic field in proportion. It is seen from Figure 5 that the plate voltage is almost directly proportional to magnetic field. The resultant effect is

Figure 6. Rieke diagram showing variation of wavelength and efficiency with load impedance. The radial co-ordinate is voltage reflection coefficient of the load on the transmission line. (Scale marked in standing-wave ratio in decibels.) Azimuthal co-ordinate is phase angle of the reflection coefficient. (Scale marked in wavelengths displacement of standing wave minimum.) Dotted lines are constant wavelength contours, numbered in centimeters above a fixed value. Solid lines are constant efficiency contours. Data taken at 1.0 ampere plate current, 1,200 gausses

ich that plate current becomes proportional to plate oltage. This ohmic characteristic gives much smaller ariations of power with plate voltage, as shown by the olid curve in Figure 7.

The series electromagnet also stabilizes the output power gainst variations in load impedance. In Figure 8 power plotted against resistance of an ohmic load, measured in erms of Z_0, the characteristic impedance of the transmission ne which it terminates. The power curve with a series lectromagnet is more constant than with fixed magnetic eld and either constant voltage or constant current from ne plate supply. Obviously, judicious choice of regulation haracteristic of the supply could help in this respect also.

One difficulty with the series electromagnet is that when ne plate voltage is first applied, the field is zero. Under

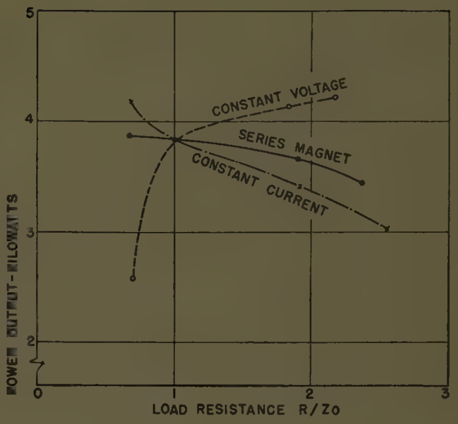
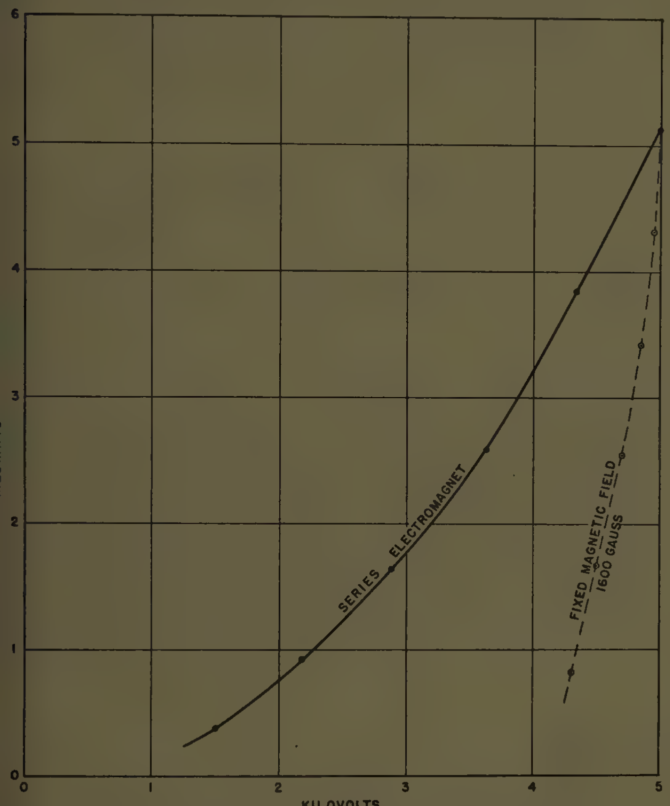


Figure 8. Variation of output power with resistance of a non-reactive load, showing the effect of power-supply characteristics



igure 7. Effect of plate voltage on output power, with fixed nagnetic field and with an electromagnet in series with the magnetron

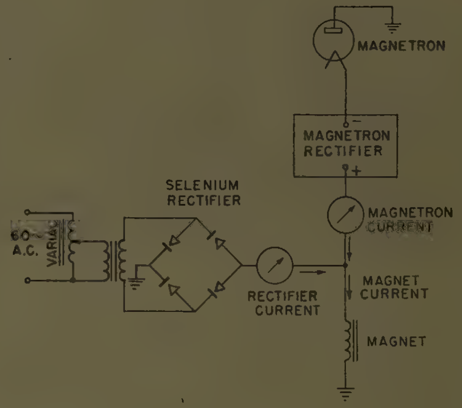


Figure 9. Auxiliary current supply for electromagnet, used for starting the oscillator and for controlling the magnetron plate current

hese conditions, the magnetron will not start in its proper node but will oscillate in a high-frequency electronic mode t a voltage too low for the proper mode to take over. The remedy for this trouble is to have a residual magnetic ield present before the plate voltage is applied. Figure 9 hows a rectifier circuit which supplies starting field by eeding current into the magnet in parallel with the plate urrent. As the plate current rises, the drop in the magnet xceeds the rectifier voltage and the rectifier stops feeding urrent.

The rectifier shown in Figure 9 has other uses. It rovides a surge path for the magnet current when the late supply is cut off, avoiding excessive voltage rise due o the inductance of the magnet.

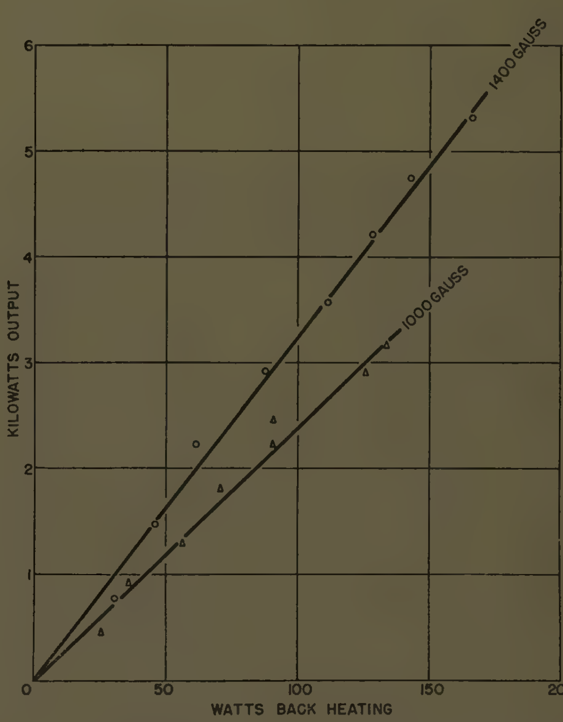


Figure 10. Back-heating of the cathode in 5-kw magnetron. These data are for a matched load

Also, with the variable a-c supply to the rectifier, it may be used as an output power control which is much cheaper than a plate power supply with continuously variable voltage. Leaving plate voltage fixed, the d-c output voltage of the rectifier is raised until it feeds shunt current into the

magnet. This raises the magnetic field and reduces magnetron plate current. In this way, continuous power output control is obtained for the magnetron with a small variable autotransformer.

Filament temperature control. One very important piece of circuitry is a device for keeping the magnetron's filament at the proper temperature. The filament receives a considerable amount of energy from bombardment by electrons which get into the radio-frequency field in the wrong phase and are accelerated, just as in a cyclotron. Most of these electrons strike the cathode. In Figure 10 is plotted

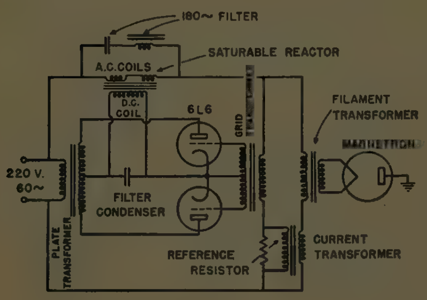


Figure 11. Constant temperature filament regulator circuit. Resistance of the magnetron filament is compared with a preset reference. Unbalanced signal is amplified and used to control filament heating current

the back-heating power in a *Z1492*-type magnetron at 1,000 and 1,400 gausses as a function of output power. These data were taken with a load matched to the output-transmission line. Unfortunately, the heating is also a complicated function of load impedance, getting worse for unloaded conditions. No device capable of anticipating its amount has been very satisfactory.

The *Z1492* cathode, running normally at 560 watts, would have its life shortened by a factor of 7 by the addition of 155 watts of back-heating, so it is worth while to compensate for it.

A regulating circuit, shown in Figure 11, compares the resistance of the filament with a reference resistor. As the filament temperature rises, its resistance increases. This generates an error signal in the servo circuit which reduces the heating current.

The circuit as shown will compensate for three-fourths of the back-heating power in a *Z1492* magnetron. More elaborate controllers with better regulation have been designed, but the circuit shown has the advantage of simplicity and of failing safe. If a tube loses conductivity, the magnetron filament becomes colder.

Radio-Frequency Transmission Lines. The *Z1492* is designed to feed into a $3^1/_8$-inch coaxial transmission line of 53 ohms characteristic impedance. Lines with dielectric beads supporting the center conductor are not desirable, due to reflections from the beads and dielectric losses in them. Stub-supported lines have been used having an inner conductor 1.250 inches in diameter and an outer

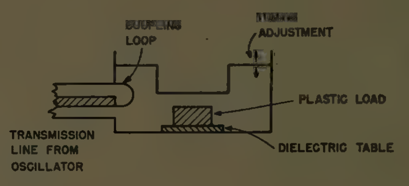


Figure 12. Resonant cavity for heating plastic preforms

conductor 3.027 inches in inside diameter, and they have been found satisfactory.

In microwave heating, even more than low-frequency heating, each job presents a new problem in coupling power to the load. One example which has been studied is the heating of precooked frozen dinners. A specialized unit for this purpose was developed by P. W. Morse and H. E. Revercomb.[1] It contains a resonant cavity, inside which the food is rotated on a phonograph-like turntable to

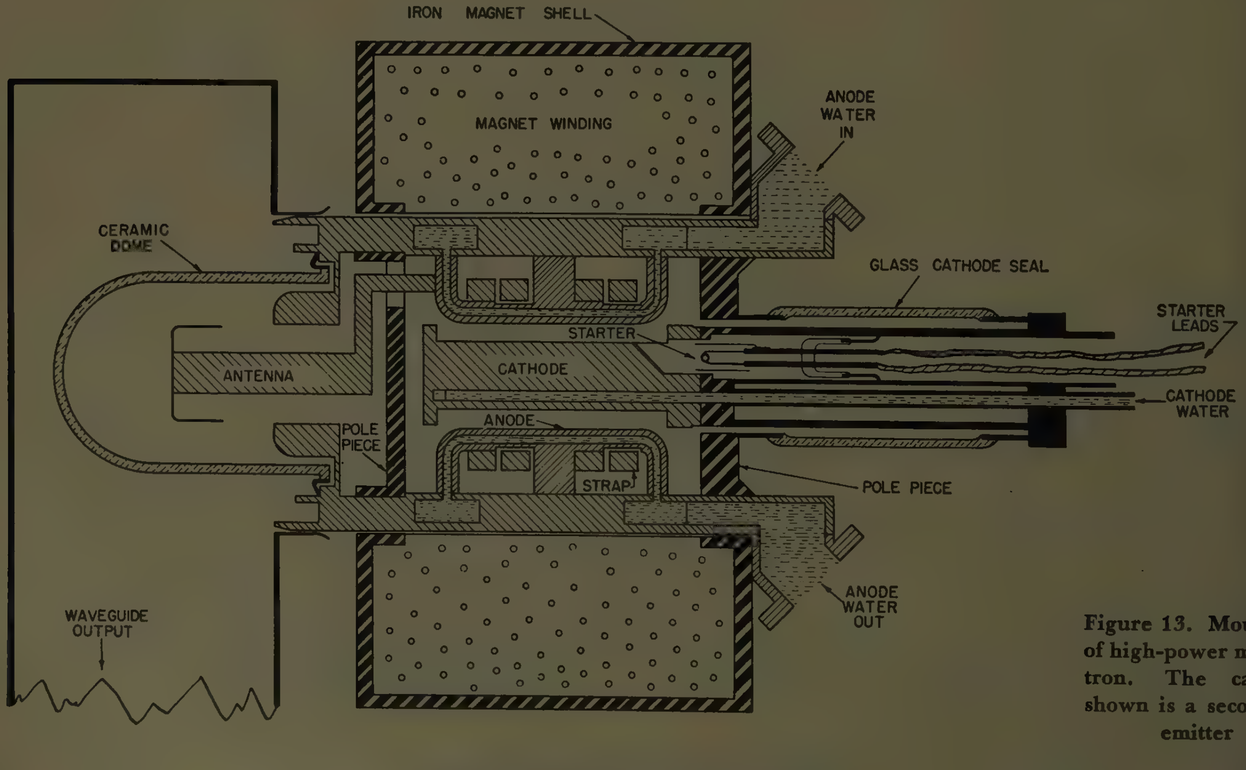


Figure 13. Mounting of high-power magnetron. The cathode shown is a secondary emitter

gure 14. Tungsten spiral cathode. Filament wires are 0.100 ch in diameter. Anode structure of high-power tube is at the upper right

erage out the standing-wave pattern. Transition from e frozen condition to edibly hot was accomplished in ne minute.

Another example of coupling methods is in the preheating thermosetting plastics. Here the pieces are small and niform, but a very even temperature is required. One ethod which has been used is the resonant cavity shown Figure 12. The transmission line is coupled by an ductive loop to the cavity, which is tuned to resonance by oving one side. The plastic preform pellet is placed at e center of the cavity in the region of most uniform field. support of low-loss dielectric prevents burning at the oints of contact with the metal walls.

In this cavity, fed with 915-megacycle power, phenolic astics can be preheated to a molding temperature of 00 degrees centigrade in one second.

HIGH-POWER MAGNETRON

EXPERIMENTAL magnetrons have been built to give up to 50 kw output at 1,000 megacycles. One such tube as developed as part of a Signal Corps contract. This agnetron operates at about 14 kv, with a magnetic field 1,500 gausses. Plate efficiency is from 50 per cent to) per cent.

At the high-power level, it is desirable to use waveuides for transmission lines. The magnetron output is esigned to couple directly into the waveguide, as shown Figure 13, by a quarter-wave antenna penetrating the uide. Surrounding the antenna is a ceramic dome hich forms the vacuum seal. The ceramic material, gh-alumina vitreous body known as "Aluminite," will and much higher powers than glass. The anode structure this large tube, shown in the insert of Figure 14, consists 16 anodes $3^1/_2$ inches long by $^1/_4$ inch wide, each carrying ooling water. It will dissipate 80 kw.

The limit on power in these continuous-wave magnetrons in the cathode, where back-heating is severe. Experients were carried on with water-cooled cathodes coated ith good secondary-emitting materials. Such a cathode is shown in the tube in Figure 13. With a secondary electron yield ratio of 3-to-1, the back-bombarding electrons generate enough secondary emission to sustain oscillations. A small thermionic cathode is used as a starter. With these cathodes, power output of 50 kw was obtained, but the life was measured in tens of hours. The secondary-emitting surfaces consisted of active metals such as magnesium and beryllium oxidized to a depth of a few hundred angstroms. In operating the tube, residual gases are ionized by the high density of electrons between cathode and anode. These positive ions bombard the cathode, and are believed to sputter off the oxide layer, leaving a clean metal surface which has a low secondary yield.

Thermionic cathodes coated with thoria were tried. Powers around 30 kw were obtained, limited by cathode-to-anode breakdown. These cathodes should have very long life. A pure-tungsten hot cathode is shown in Figure 14. It has a maximum heating power of 5 kw. With it, outputs of 35 kw were reached, limited by back-heating of the cathode exceeding its total power requirement.

The conclusion from these high-power tube tests is that we now know how to build a good 30-kw oscillator at 1,000 megacycles.

REFERENCE

1. UHF Heating of Frozen Foods, P. W. Morse, H. E. Revercomb. *Electronics* (New York, N. Y.), volume 20, October 1947, page 85.

17,000,000-Volt Linear Accelerator

Electrons race down the 21-foot length of this 17,000,000-volt linear accelerator now in use in the Laboratory for Nuclear Science and Engineering at the Massachusetts Institute of Technology. The new machine will be used for nuclear research on the ultimate nature of matter

INSTITUTE ACTIVITIES

Fourteen Technical Sessions Held at AIEE Great Lakes District Meeting

A wide range of subjects was covered in the 14 technical sessions of the AIEE Great Lakes District Meeting held at the Loraine Hotel, Madison, Wis., May 17–19, 1951; the attendance was 626 members, students, and guests.

OPENING SESSION

J. R. North, AIEE Vice-President of the Great Lakes District, presided over the opening session and introduced Governor Walter J. Kohler of Wisconsin, who welcomed the guests to the city and state. He congratulated his audience on being members of a great profession who have contributed so much to the American way of living.

Mr. North then introduced AIEE President Titus LeClair who told that when he first became interested in the Institute, it had approximately 7,000 members. Now that number represents the personnel serving on the various committees. This is illustrative of the growth of the AIEE, most of which has occurred in the last ten years, and it must continue to grow.

Approximately three per cent of this country's population is engaged in some phase of engineering and there is a need for more engineers. In 1951 it is estimated that only 30,000 engineering graduates will be available to industry; next year there will be about 21,000 with fewer in 1953 and in 1954 only about 15,000. This decrease of young engineering manpower is a serious problem which should receive the attention of the Institute members, who are urged to explain to the parents of high-school pupils and to the pupils themselves that this future shortage of engineers must be relieved and that opportunities in the engineering field are better than ever.

Because the electrical engineering profession is progressing at such an accelerating pace, specialization is inevitable. This means that more technical papers should be presented at Institute meetings with an attendant increase in costs. Within the year this problem will be solved.

President LeClair has asked that appropriate machinery of the Institute be set up to appoint committees because it is impossible for the president to know the qualifications of all the committee personnel. The Committee of Planning and Co-ordination has this and other problems now under consideration.

A plea for greater unity on the part of the Institute membership was made. A spokesman is needed who can present engineers' problems before legislative bodies. The President reminded his audience that they will get out of the Institute what they put into it and asked that they work harder than ever for AIEE.

Mr. North next introduced C. F. Wagner, consulting engineer with the Westinghouse Electric Corporation, who spoke on "Corona Effects on Transmission Lines" with data based on tests made on the Tidd test project at Brilliant, Ohio.

Two sets of data were obtained, one covering corona loss and the second dealing with radio influence. After the conductors of the test line had been aged at the maximum voltage at which the runs were made, it was found that different results were obtaine with the same electrical conditions on differ ent days. The reasons given were tha under some conditions dust particles adhere to the conductors' surfaces and in som other instances the surfaces themselves wer altered due to atmospheric condition The results showed long time averages fo fair and foul weather are best and unde these long term conditions moisture on th conductors showed a greater loss than i current had been flowing through them The corona of a heated conductor was les than one in which current was not flowing Furthermore changes in electrostatic condi tions due to the weather changed the groun gradient, but there was change in the loss.

The speaker described the corona measur ing equipment and its use; the difficultie in making measurements and how th problems were solved under all sorts o weather conditions.

Radio-influence measurements have bee made with standard radio-noise and field intensity meters as well as radio receivers fo amplitude- and frequency-modulated re ception and television receivers. The radi loss varies with atmospheric conditions an it can be reduced by balancing the lines In television tests it was found that at distance of 45 miles from the transmittin station there were no changes in the receive picture.

The speaker emphasized that only b averaging out the losses can useful data b determined. Corona studies should b made in the field under all weather condi tions. It was further recommended tha corona itself should be studied as well a radio influence, which will doubtless dictat the design of the lines.

The presentation by Mr. North of th Best Paper Prizes for 1949–1950 in District followed. The first prize of $75.00 an certificate was awarded to W. G. Dow an H. A. Romanowitz for their paper, "Statis tical Nature and Physical Concepts o Thyratron Deionization Time." The secon prize of $50.00 and certificate was won b E. E. George, H. W. Page, and J. B. War for their paper, "Co-ordination of Fuel Cos and Transmission Loss by Use of the Networ Analyzer to Determine Plant Loadin Schedules."

Electrical World photograph

Shown at the opening session of the Great Lakes District Meeting are: Walter J. Kohler, Governor of Wisconsin; J. R. North, AIEE Vice-President of the Great Lakes District; Carl C. Crane, Chairman of the District Meeting Committee; C. F. Wagner, speaker at the meeting; and AIEE President T. G. LeClair

BANQUET

The banquet was held on Thursda evening at the Memorial Union on th campus of the University of Wisconsi after which excellent entertainment wa provided by student talent. The high spo of this was a series of songs by the Men Chorus of the University under the directio of Professor Paul Jones.

LUNCHEON MEETING

The feature of a well-attended luncheo meeting on Friday was an address, "Researc in a Defense Economy," by Dr. J. E. Hobso Director, Stanford Research Institute. Th speaker emphasized that in the present de fense economy, all efforts toward organize research both within the government and i

try should be redoubled, particularly as eers and scientists are in short supply. step in the right direction he referred to to establish applied research institu- in Germany and Italy.

th a view toward improving the effi- y of research workers, Doctor Hobson of a research psychological study under at the Stanford Research Institute to tigate the effects of environment and re the factors involved in maintaining ative and stimulating research atmos- . Results so far are inconclusive but have enabled the rendering of assistance dividuals.

e speaker urged that research for defense ndertaken along with research in the ediate commercial interests of the com- , and he warned that if industry did not a large part of the load of defense re- h in a free-enterprise system, the govern- would do it. The company that selects nment research in those areas where it ain knowledge that can be applied to its nercial activities will be way ahead of its etitors.

stated that a group of organized re- hers in industry, a university, or an endent organization is an important nunity asset and a vital part of our basic nal resources. The complete address be published in a subsequent issue of *rical Engineering*.

A. Peterson, Vice-Chairman of the ict Meeting Committee, introduced the rs at the speaker's table. President air, on behalf of the Board of Directors, plimented Chairman Crane and the ict Meeting Committee on the quality e meeting. He was particularly im- ed with the excellent presentations in tudent session.

STUDENT BANQUET

e Student banquet was held May 18 in Memorial Union Building of the Univer- of Wisconsin, with Robert A. Susdorf as master. The address was given by V. Seeger, Vice-President in Charge of elopment, Cutler-Hammer, Inc., who

Attending the Great Lakes District Meeting are, left to right: John Baird, Councilor, University of Wisconsin Branch; T. J. Higgins, University of Wisconsin; R. E. Johnson, Chairman of the Committee of Judges of Student Papers; M. O. Withey, Dean, College of Engineering, University of Wisconsin; H. A. Peterson, University of Wisconsin

previously had received a citation award from the University of Wisconsin as an outstanding engineer in the region. In view of the short supply of engineers and the present manpower situation, the speaker counseled against overoptimism. He cited that one or two years ago there was an oversupply of engineers; at that time those about to enter the field of employment would have to be good to live through that situation.

In the present situation engineers, teachers, and all engaged in the profession would have to work harder, upgrade the engineers, and use technicians where possible. However, on the opposite side he pointed out that there never has been an oversupply of engineers for any length of time.

With respect to the high character of the profession, the speaker felt that those about to enter the field of engineering were very lucky as we live in the best country in the world, and production has brought about a standard of living that is better than anywhere else. Furthermore, he felt that graduates were entering the best business in the country and that the nicest people were those working on development work.

In conclusion, Mr. Seeger suggested that the following points should be kept in mind: Make up your mind as to what you think success is—money, happiness, accomplishment, or security. The man who sets out to have a definite goal and who keeps at it will achieve it. Further, each graduate has a debt to society, a responsibility toward the community, society, and education. This responsibility cannot be shed because one is educated. He suggested reading what the late W. E. Wickenden, Everett S. Lee, and President T. G. LeClair have said about the engineering profession. He quoted Theodore Roosevelt as saying that the first requirement of a good citizen of this republic was that he should be ready and willing to pull his own weight.

The winners of the Student Prize Paper Awards were announced by R. E. Johnson, Chairman of the Judging Committee. He complimented the authors of both the undergraduate and graduate papers on the versatility and competence of the presentations with topics so varied that the judges found it difficult to decide on the awards in some cases. Young engineers who write good reports are the ones who advance most rapidly. The winners of the undergraduate awards were as follow:

First Prize. "Improving Servo System Response with a Nonlinear Amplifier" by E. Meagher, University of Notre Dame.

Second Prize. "A One-Cycle Radio Interference Filter" by R. W. Nelson, North Dakota Agricultural College.

Third Prize. "Electronic Digital Computers" by B. W. Lillick, State University of Iowa.

Honorable Mention:

"Cathode Ray Oscilloscopes as Industrial Measuring Tools" by J. W. Wilder, Illinois Institute of Technology.

"The Transitor, a Crystal Rectifier" by A. L. McWhorter, University of Illinois.

"The Vectograph" by R. Fleming and N. E. Quinn, University of Detroit.

The winners of the Graduate Prizes were:

First Prize. "Design and Construction of Infra-Red Detector for Locating Broken Strands in Overhead Transmission Lines" by M. W. Oleson, University of Wisconsin.

Second Prize. "Electromechanical Analogue of a Synchronous Machine" by J. E. VanNess, Technological Institute, Northwestern University.

Honorable Mention. "Linear Actuators" by G. T. Flesher, Illinois Institute of Technology.

Prof. H. A. Peterson extended a cordial welcome on behalf of the University of Wisconsin to the students attending the banquet. For many, it was their first experience attending an AIEE meeting and he expressed hope that they would attend many more.

STUDENT BUSINESS MEETINGS

Student Branch Counselors Meeting. Following the banquet, a meeting of the District Committee on Student Activities, with H. S. Dixon as Chairman, took place until 10 p.m. and reconvened next morning at the Engineering College.

The minutes of the last meeting were ap-

Future AIEE Meetings

fic General Meeting
nomah Hotel, Portland, Oreg.
ust 20–23, 1951
l date for submitting papers—closed)

E Conference on Aircraft Equipment
ywood Roosevelt Hotel
Angeles, Calif.
ber 8–10, 1951

E Conference on Fractional Horse- er and Motor Applications to Re- ration Equipment and Pumps
on, Ohio
ber 11–12, 1951

General Meeting (*page 644*)
l Cleveland, Cleveland, Ohio
ber 22–26, 1951
l date for submitting papers—closed)

ter General Meeting
l Statler, New York, N. Y.
ary 21–25, 1952
l date for submitting papers—October 23)

proved as mimeographed and distributed.

A report of a special committee to study the rules under which the District Committee on Student Activities is functioning was presented by the Chairman of the committee, E. T. B. Gross. The committee recommended continuation of the study.

With regard to the rules governing the awards of undergraduate and graduate branch paper prizes, two problems were presented. One was in the case of papers prepared when the student was an undergraduate but the contest is not held until after graduation. The other was in the case of the graduate prize where a man served as an instructor for several years and then came back as a graduate student. It was the feeling that papers which exceed 12 typewritten pages and six illustrations which do not meet the requirements must be disqualified. For undergraduate papers, 50 per cent for the written presentation and 50 per cent for the oral presentation was believed satisfactory. However, the view was expressed, in the case of the graduate papers, that greater weight might be given to the originality of the subject and the written paper than the oral presentation. Professor Gross' committee was asked to take these matters under advisement in its continuing study.

In accordance with the rotational scheme, Prof. E. T. B. Gross was nominated as a Junior Member of the District Committee on Student Activities with Prof. E. A. Reid as Chairman for the coming year, and Prof. E. B. Kurtz as Senior Member.

Consideration was given to the location of the next Student Branch Convention and invitations from the Dakotas, University of Illinois, and Michigan College of Mining and Technology were considered. While there never had been a Student Branch Convention in the Dakotas, nevertheless the feeling was that the location was a little too remote and the committee voted to recommend to the incoming committee that the next Student Branch Convention should be held at the Michigan College of Mining and Technology at Houghton.

The committee voted to commend the Student Branch at the University of Detroit for the appropriate action taken following the death of the late Prof. H. O. Warner.

Branch Chairmen and Counselors Meeting. The chairmen and representatives of the Student Branches in the District each presented brief reports on their activities. The Iowa State College Branch reported an interesting project where a workshop had been established for the repair of donated radios which are given to orphanages and old peoples' homes. Purdue University reported holding a first annual open house which proved highly successful. This branch has 501 members, all of which are national. Dues of one dollar are collected just once and at the same time national membership is solicited. Rose Polytechnic Institute reported a high percentage of attendance at eight meetings which are strictly business and all of their members are national members. Michigan College of Mining and Technology reported giving an engineering show which was well attended. A number of the branches reported on a variety of activities such as technical paper presentation meetings, prominent speakers from industry, industrial movies and shows such as "Motors on Parade," the Westinghouse show, "Adventures in Research," and "General Motors Features of Progress." With the short supply of engineers, an activity of worthy interest seemed to be the holding of open house or engineering days where laboratory equipment and demonstrations were set up with a view toward interesting high-school students in engineering.

President LeClair stayed over to join the meeting because he felt that he did not get enough opportunity to keep in touch with student activities. These activities were important because a very large percentage of the members and leaders of the Institute came from the student branches. He advised that it was well worth while to take time to attend a student technical session and he expressed the wish that older engineers who have spent considerable time in the preparation of papers would attend a student technical session and see how well the papers are presented.

President LeClair felt that the practice of inviting prominent speakers from industry to address the student meetings was a valuable one because the professors do not have the time to give the vast variety of detasls with which engineers from industry are familiar. He explained that the steady trend of interest in electronics in recent years because new things have been made more glamorous has given the power industry concern. He pointed out that within his own company there was much communication work, 200 mobile units, carrier relaying, electronic apparatus, and electronic heating, as well as work on atomic fission. With respect to opportunities, he pointed out as an important factor that too many engineers were employed in the 1920's and too few in the 30's and 40's.

In conclusion, President LeClair expressed hope that many of the branches would have speakers from the power and electrical manufacturing industries next year. In this way, a true picture from those in the various branches of power work and manufacturing could be obtained.

General Discussion. A general exchange of views took place in regard to the operation of the branches. Purdue University Branch reported filling two offices with juniors so that when the executive committee, who are seniors, graduate, continuity of the work will be provided. The importance of getting the magazine was stressed when obtaining student enrollments. The Michigan College of Mining and Technology Branch reported that its incoming officers worked with the officers of the previous year and that attempts were made to get freshmen and sophomores as secretaries and treasurers. The Rose Polytechnic Institute Branch advised that it had no contact with students until they were juniors. The suggestion was made that a representative should contact the students in the physics classes or that the sophomore electrical engineering instructor should make it a point to stress the importance of the AIEE.

When presenting papers, Mr. Nelson expressed the view that if the time of presentation is cut down, some important point might not be brought out, and that if a number of papers are presented the time cannot be stretched out. President LeClair emphasized the importance of putting a point over simply and quickly and it was his opinion that the most difficult and complex st[ory] could be told in ten minutes and that it i[s a] better story than a 20-minute presentati[on]. From personal experience in connection w[ith] obtaining appropriations, he advised tha[t if] the story cannot be told in one page it is di[ffi]cult to obtain the money for an expenditu[re].

The difficulty of getting a good attendan[ce] at meetings in the large schools was stress[ed] and the suggestion made that more attem[pts] should be made to co-ordinate the tim[e]. One counselor expressed the view that t[oo] much emphasis was put on the writing [of] reports, quizzes, and so forth, and n[ot] enough time is placed on professional acti[vi]ties. It was believed important that t[he] faculties should spend considerable time [in] several periods stressing the importance [of] student meetings and their benefits, a[nd] that they should attend themselves. T[he] representative of the Rose Polytechnic Ins[ti]tute Branch advised that their meetings we[re] entirely informal and the faculty was n[ot] always present. Another view brought o[ut] was that the chairman of a local bran[ch] should be a good salesman and sell the st[u]dents as well as the faculty on the idea. [It] was believed the initiative should come fro[m] the students and that the faculty was 1[00] per cent back of the AIEE. One of t[he] branch chairmen expressed the idea that [if] the faculty cannot afford the time to atte[nd] the meetings he did not see how the studen[ts] could afford the time.

At the conclusion of the meeting, attenti[on] was called to the pamphlet on student gui[d]ance put out by the Engineering Council [for] Professional Development.

TECHNICAL SESSIONS

Generating Stations Equipments Session. (Fi[ve] papers were presented the afternoon of M[ay] 17 with J. P. Madgett, Jr., presiding. T[he] first paper dealt with an engineering a[p]proach to control room lighting and it w[as] presented by V. L. Dzwonczyk of the Ame[ri]can Gas and Electric Service Corporati[on]. The author analyzed the lighting syst[em] problem from the point of view of providi[ng] the operators with the lighting system th[at] would enable them to perform their visu[al] tasks efficiently, and he also considered h[ow] best to use the many available new lig[ht] sources that are economically reasonab[le]. Major considerations that enter the desi[gn] of a satisfactory modern control room lighti[ng] system were set forth and a direct lighti[ng] system using commercially available troff[ers] in conjunction with a special, but not dif[fi]cult to construct, ceiling design was describe[d].

In the second paper, G. Schilstra describ[ed] the control system of the new 60,000-[kw] Edgewater Generating Station of the W[is]consin Power and Light Company.

The next two papers represented a revi[val] of interest in using the induction machine [as] a generator. The installation of an 1,800-[kw] 4,160-volt induction generator in the W[...] Dam Plant of the Wisconsin Michig[an] Power Company was described by H. [...] Brown. This generator is driven by [a] 2,500-horsepower 225-rpm vertical fix[ed] propellor turbine. The unit has the adva[n]tage of producing kilowatt hours at t[he] lowest possible cost, and it requires no excit[er], rheostats, governor, or costly synchroniz[ing] equipment. It is ideal for automatic ope[ra]tion and permits use of relatively inexpe[ri]enced operators. Placed in service in 19[...]

,000 kilowatt-hours have been generated without effect on other parts of the system. Phase-to-phase and phase-to-neutral tests indicated good sine-wave conditions, disturbances have been absorbed, and it is relatively free of harmonics. In response to a question, the author explained that phasing out was accomplished from the manufacturers' directions in respect to sequence and direction of rotation and they used a synchronous machine on the system about 20 miles away which could be isolated.

The fourth paper, entitled "Squirrel Cage Induction Generator for Power Generation," by C. C. Tsao and N. F. Tsang, considered technical aspects of three general situations where the use of induction generators might be feasible such as when driven by turbines, when used to support synchronous machines, and when operated in combination with capacitors to supply relatively large-scale power in any system. In response to a question in discussion which showed concern about the small air gap clearances, Robert Moore of the Allis-Chalmers Manufacturing Company advised that the designer has had considerable experiences such as are encountered in circulating water pumps.

The fifth paper, by John H. Schroeder of the Commonwealth Edison Company, dealt with the control room at the Richland Station. The dimensions and positioning of all the various benchboards and gaugeboards as well as the room lighting, gauge lighting, the cable room below, and the intercommunications system, were explained by the author. In connection with units 3 and 4, a question arose as to why the load divided of 40,000 kw in the high-pressure unit and ,000 kw in the low-pressure unit. President LeClair explained that it was more efficient to run the steam through one turbine than to take it back to the boiler.

Servomechanisms Session. Three conference papers and a technical paper devoted to the theoretical aspects of servomechanisms comprised one of the opening technical sessions on the afternoon of May 17th. N. Schmitz, University of Wisconsin, was chairman.

The first paper, "Multiple Mode Operation of Servomechanisms" was presented by Donald McDonald, Cook Research Laboratories. Normally only one mode of operation of servomechanisms is considered in analysis for the sake of simplicity, but all servos have at least two modes or equations of motion. The controllers for continuous servos are usually adjusted to yield optimum performance in the standard or linear mode and to give tolerable operation when the system is in its additional modes. If a servo has multiple modes of operation, its over-all performance could be improved if the controller were designed to take the greatest advantage of the system's characteristics for each mode of operation. The design of a controller was described which makes use of the additional modes of operation and which produces a servo which has better response with less weight than the servos designed for only one mode of operation.

A conference paper, "Transient Response of Two-Phase Induction Motor Type Servomotor," was presented by K. Fong, University of Illinois, and a technical paper, "Transient Response of Small, Two-Phase Induction Motors" was given by A. M. Hopkins, Northwestern University. Both of these authors presented an analysis of these important induction motors and derived the differential equations pertaining to the various characteristics.

The final paper of the session was presented by L. O. Brown, Jr., University of Illinois, and was titled "Transfer Function for a Two-Phase Induction Servo Motor." An analysis was made of a 2-phase servo induction motor which results in a transfer function having two time constants. A method for determining the magnitudes of these time constants from a knowledge of the inertia and friction of the motor and the load in addition to the steady-state speed-torque characteristics was also given.

Transmission and Distribution Session. E. J. Kallevang presided at the Friday morning session, where six papers were presented. The first paper, by F. W. Linder of the Dairyland Power Co-operative, dealt with the design and construction of a 71-mile 138-kv transmission line from the Alma Steam Station to the Genoa Station along the east side of the Mississippi over rugged terrain. In this region, there are bluffs approximately 500 feet above the river elevation which are cut up by coulees which range from 1,000 feet to over one mile in width. H-frame type of construction was employed with two ground wires and a maximum structure footing resistance of 20 ohms was maintained in so far as feasible. The second paper, by Howard K. Amchin and Eric T. B. Gross, analyzed and discussed the methods of extending solutions to subsequent faults on power systems where a single-line to ground fault is not a short circuit. Among the methods considered were the sequence network connection method which is based entirely upon symmetrical components, the network connection method by Clarke components, the superposition principle applied to the network connection methods, the equivalent Y and modified equivalent Y methods. The presentation, with the aid of slides, was made by Mr. Amchin.

The third paper presented dealt with symmetrical components as applied to protective relaying and the author, W. K. Sonnemann, expressed hope that the presentation would contribute toward a better understanding of the usefulness of the symmetrical component concepts as a powerful tool in the solution of relay application and design problems. In discussion, Prof. Eric T. B. Gross raised a question concerning the terminology in the paper and the use of the word "filter" in place of which he suggested the term "network."

The fourth paper was by H. C. Brem of the Allis-Chalmers Manufacturing Company and dealt with the low-cost voltage regulation of rural distribution lines. The author dealt with the reasons for voltage regulation, how it is accomplished, and where it is applied, and he discussed the station type of equipment as well as line-type equipment. With respect to the economics, Mr. Brem pointed out that the installation of a regulator avoids the need to change conductors, no substation is required, and there is no more installation cost than that for a transformer. The attendant advantages are better service, improved public relations, and increased power consumption, and the regulator can earn its investment in a year.

The fifth paper was presented by L. W. Matsch of the Illinois Institute of Technology. An analysis supported by experimental data of 3-phase dielectric power-factor measurements was made and the sources of error in the measured power factor were considered. The author showed that the true power factor can be obtained by taking the average of the values measured on any individual phase with voltages first of one phase sequence and then of the opposite phase sequence.

The last paper, which was presented by title only, dealt with the effect of the duration of voltage dip on cyclic light flicker. In discussion, R. E. Young of the Public Service Company of Northern Illinois explained that the paper considered a type of voltage flicker which could not be handled by the induction type of regulator. He explained that the problem was a continuing one which he wished to emphasize and he hoped that the paper would stimulate more work on the subject.

Basic Sciences Session. The session on basic sciences held the morning of May 18 was presided over by Walther Richter, Allis-Chalmers Manufacturing Company. The first paper, "Dependence of Direct Sparkover Voltage of Gaps on Humidity and Time" was by P. B. Jacob, Jr., Mississippi State College, and G. M. L. Sommerman, Northwestern University, and was read by the latter. For air between smooth spherical electrodes, the direct spark-over voltage is practically independent of the humidity and critical withstand values are not much less than the short-time spark-over values. For air between standard square-edged rod electrodes, the direct spark-over voltage is erratic. If direct voltage is applied rapidly to the rod gap, the initial spark-over voltage increases with increasing humidity similar to 60-cycle behavior. There is a marked decrease in spark-over voltage with time of voltage application and this seems to become greater with increasing humidity. In the design of electric equipment for operation in air at high direct voltages, it may be important to use electrodes with no sharp edges.

The second technical paper was presented by T. J. Higgins and D. K. Reitan, both of the University of Wisconsin, and was read by the latter; its title was "Calculation of the Capacitance of a Circular Annulus by the Method of Subareas." This paper advances the theory of an approximate method for calculating, to any degree of accuracy, both the charge distribution and the capacitance of a plane area charged to a potential by a certain charge. This theory's application is illustrated by calculating the charge distribution and capacitance of an annular area. Thus far, a solution for finding the potential has been found for only two plane areas: the elliptical disc and the circular disc; therefore, the equations for the charge distribution and capacitance are likewise only known for these two areas. A single curve, the ratio of the capacitance to the outer radius of the annulus plotted against the ratio of the outer to the inner radius, where the latter ratio ranges from unity to infinity, gives the capacitance of an annulus of any desired radii.

"The Magnetic Cross Valve" was read by by H. J. McCreary, Automatic Electric

Company. This electromagnetic device, having two stationary coils with no mutual inductance to each other, transfers energy from one coil at one frequency to the other coil at a second frequency by means of a field of flux which follows a Lissajous locus or mode of motion. It was compared to a rotary electromagnetic device where the Lissajous figure, the circle, is used and to the transformer which has only one degree of freedom. The author demonstrated different cross valves as power converters, one being a power telephone ringer converting 60-cycle to 20-cycle power.

P. M. Kintner, University of Illinois, presented "Magnetic Amplifier Analysis Using Flux-Charge Theory." In considering the charging of a capacitor, it is natural to visualize a charging current as charging the device to a certain value of voltage; this could be termed a voltage-charge of the capacitance. The action for a reactor could be described analogously as a charging voltage charging the reactor to a new value of flux or as producing a flux-charge of the device. If a point of reference is established on a magnetization curve, the particular state of magnetization of a reactor can be defined in terms of quantity of flux charge. The significant point is the saturation point of the magnetization curve and this is chosen as the reference point. The flux-charge concept is most applicable to the type of analysis where a linear-region approximation of the magnetization curve is made, for the saturation points with this type of approximation become discontinuities and offer definite points of reference.

The author illustrated the application of the flux-charge concept to magnetic amplifiers by analyzing the series-connected amplifier and the discussion was limited to the case where the load and control circuit impedances are purely resistive. This was shown to be a useful method of describing the mechanism of operation of the device and gives a derivation of the input-output relationship and transient response of the series-connected amplifier.

"Change of Units and Conversion Formulas" was the title of the paper presented by V. P. Hessler, University of Illinois. In determining the conversion factors between two absolute systems, actual comparison of physical sizes of quantities need be made only between the fundamental quantities of the two systems. For example, in two unit systems in mechanics based on length, mass, and time, the conversions between the length units, the mass units, and the time units must be determined by direct comparison but all other conversions may be derived by algebraic manipulation of the defining or convenient relations. Following an explanation of his conversion formula, the author gave examples of conversion formulas for derived units and the conversion between rationalized and unrationalized quantities. He distributed a set of physical and electrical conversion formulas derived by his method.

G. R. Town, Iowa State College, presented "Electric and Magnetic Units and Dimensions in the EMU, ESU, and MKS Systems." The advantage of the meter-kilogram-second system is apparent in that electrical quantities are measured in familiar units: volts, ohms, watts, and so forth, rather than in unfamiliar units which are easily forgotten. Another advantage is that the permeability and permittivity of free space (μ_0 and ϵ_0) are not unity. In systems where these are unity, these quantities are often omitted from equations in which they should appear as multiplying factors. When such equations are applied to situations in which the permeability or permittivity is not unity, the results are in error. There is also the confusion in dimensions and units. The author's purpose was to show the fundamental principles upon which a conversion table can be based; in particular, the dimensions of μ_0 and ϵ_0 were discussed.

"The Transient Response of Magnetic Amplifiers—Cases of Negligible Commutation" by L. A. Finzi and D. P. Chandler, Carnegie Institute of Technology, and D. C. Beaumariage, Sperry Gyroscope Company, was presented by title only.

Electrical Machinery Session. Five papers were presented Friday afternoon and a sixth was presented by title only. W. A. Lewis presided. In the first presentation, visiting Prof. Y. H. Ku of the Massachusetts Institute of Technology outlined the methods of transient analysis of rotating machines and stationary networks by means of rotating reference frames.

The second paper, by C. H. Crouse of Robbins and Myers, Inc., dealt with a design method for polyphase reluctance synchronous motors. He explained by a method of synthesis how to choose a winding from constants; credit for the diagram was given to P. H. Trickey. The method presented represented another step along the line of designing to meet the specifications.

The third paper, by George V. Mueller of Purdue University, dealt with the effects of unbalanced loading in a core-type transformer.

The fourth paper, with G. H. Fredrick of the Dynamic Corporation as author, dealt with the history, basic principles, speed torque characteristics, and cooling of eddy-current torque generation devices. The author concluded that this principle had been applied with outstanding success not only to adjustable speed drive units but to power absorption brakes and dynamometers. In the present emergency, there are thousands of eddy-current dynamometers and brakes being employed in testing engines, transmissions, and other components of aircraft and ordnance material.

The fifth paper on the self-starting compensated synchronous motor by K. L. Hansen, R. W. Greer, and C. M. Snapp of the Milwaukee School of Engineering, represented a noble approach toward minimizing the reactive kilovolt-ampere losses on systems. The authors explained that capacitors at best represent a makeshift solution and they do not provide for automatic neutralization of the reactive component with the load. R. W. Greer, who made the presentation, explained that the purpose of the investigation was to try to combine the accentuated desirable starting characteristics of the induction motor with the excellent running characteristics of the synchronous motor without introducing undue complications.

Electrical Measurements Session. Four papers were presented at this session, presided over by R. E. Johnson. The first, "The Three-Phase Oscilloscope as an Harmonic Analyzer in Power Systems," was by E. B. Kurtz, State University of Iowa, and R. H. Burkhardt, Electronics Laboratory, San Diego, Calif. Among its many uses, the 3-phase oscilloscope can be used as a harmonic analyzer in polyphase power systems through its use of revolving flux fields in its polyphase deflection system. The authors showed how it is possible to determine the order of harmonics if present, the harmonic's magnitude, and the phase sequence of the harmonic, that is, whether it is positive or negative with respect to the fundamental frequency.

"Piezoelectric Crystals as Sensing Elements of Pressure, Temperature, and Humidity" was presented by E. A. Roberts and P. Goldsmith, Armour Research Foundation, and read by the former. In the measurement of atmospheric pressure two different methods were discussed. They are the effect of air pressure on the Q of a low-loss piezoelectric crystal and the change in frequency of a thin quartz oscillating plate produced by differential air loading.

An oscillating piezoelectric crystal with a high temperature coefficient of frequency can be employed for temperature sensing. This coefficient is a function of the thermal coefficients of stiffness and expansion. The magnitude of this coefficient of frequency depends on the mode of vibration and the orientation of the crystallographic axis. Of the synthetic crystals available ethylene diamine tartrate (EDT) appears to be the most suitable for temperature sensing in view of its high physical and chemical stability under all atmospheric conditions.

The method of measuring humidity with a piezoelectric crystal involves the deposition of moisture on its vibrating surfaces and the use of the resulting change in oscillating characteristics to maintain the crystal at the dew-point temperature. The humidity crystal, in addition to collecting moisture and indicating its presence by a decrease in vibrational amplitude, serves as its own thermometer to indicate dew-point temperature.

E. A. Farber, University of Wisconsin, presented "Free Convection Heat Transfer from Electrically Heated Wires." The author discussed the heat transfer by free convection from electrically heated copper and iron wires to water between freezing and boiling, to water boiling at atmospheric condition, and to air at room temperature. The wire surface temperature was calculated from the theoretical temperature distribution in the wire. Experimental results show heat transfer rates of approximately 2,200,00[illegible] Btu per hour per square foot near freezing and 450,000 Btu per hour per square foot near boiling. As the temperature difference between the boiling water and the wire surface is increased, the heat-transfer coefficient first increases reaching a maximum, then decreases reaching a minimum, increasing again when the heat transfer by radiation becomes important. For copper a maximum film coefficient of 9,100 Btu per hour per square foot per degree Fahrenheit was observed at 49 degrees difference and a minimum of 136 at 690 degrees difference. Corresponding values for iron are 12,3[illegible] at 33 degrees difference and 142 at 6[illegible] degrees difference. For heat transfer to air the heat-transfer coefficients for copper with an oxide film varied from 0 to 30 and for iron with an oxide film from 0 to [illegible]

per hour per square foot per degree renheit.

he final paper of the session was "A nplex Wave Synthesizer" by G. Ferrara R. L. Nadeau, both of the University of roit. The electromechanical synthesizer its cathode-ray oscilloscope display was nonstrated. After describing methods producing nonsinusoidal waves which e been tried in the past, the authors nd that discs whose circumferences were so that their radii varied sinusoidally ld vary the output of a photoelectric in the same way. A series of ten such s (the first with three sine waves on its phery, the second with six, the third nine, and so on to the tenth which had each with its source of light and photo-tric cell, provided a means by which ages could be combined so that their l would represent a complex waveform. neans of individual controls the amplitude phase of each harmonic could be varied independently so that the waveform shown on the oscilloscope can be composed of any or all of the harmonics from the second up to the tenth of the fundamental.

DISTRICT MEETING COMMITTEE

Members of the District Meeting Committee which made the arrangements were as follows: Carl C. Crane, *Chairman;* Harold A. Peterson, *Vice-Chairman;* W. T. Stephens, *Secretary;* J. R. Hafstrom, *Treasurer;* H. Cole, C. D. Malloch, I. B. Baccus, A. H. Lovell, C. E. Parks, D. D. Ewing, Eric T. B. Gross, J. F. Calbert, J. D. Ryder, M. S. Coover, H. S. Dixon, H. E. Hartig, J. F. H. Douglas, W. Richter, *Members at Large;* T. J. Higgins, *Technical Program;* L. A. Hesse, *Inspection Trips;* G. Ansel, *Entertainment and Sports;* F. D. Mackie, *Transportation;* R. E. Purucker, *Publicity;* G. C. Neff, *Finance;* E. J. Kallevang, *Registration and Housing;* Mrs. W. T. Stephens, *Ladies' Activities;* Dr. John Baird, *Student Activities.*

ound Table Panel Featured at North Eastern District Meeting

)ne of the features of a 3-day meeting of North Eastern District held in Syracuse, Y., May 2–4, was a round-table panel on topic, "The Assignment and Developnt of the Engineer as a Professional Man." in this topic was an important part of an ress, "Engineering—Its Future," given he banquet on Thursday evening. The gram was comprised of six technical ses-s, two student sessions, inspection trips to rby industries, a stag smoker, banquet, special events for the ladies. Approx-tely 340 members and guests attended.

SIGNMENT AND DEVELOPMENT OF THE ENGINEER AS A PROFESSIONAL MAN

his important topic was presented by a el of five speakers all well qualified in the l of engineering to express their ideas and nions which represented the points of v of the power industry, the New York te Engineering Board of Examiners, elec-al manufacturing, and education. Fol-ing the presentations, the speakers wered questions from the floor. The pre-ng officer was P. F. O'Neill.

he first speaker, J. L. Haley, Vice-sident, Niagara Mohawk Power Corpora-, analyzed the attributes of a professional n. Beginning with the dictionary defini-of a professional, he stated that the pos-ion of a diploma was merely proof that had met the prescribed courses and that cation too often ended there. Later a often discovers that he has not acquired roader education. He explained that the nse means just what it says on it. Sum-rizing the requirements of a professional , the speaker said that he should be an cated man in the broader sense, a good zen, and active in the community. In clusion, he stated that the acquirement rofessional status in the eyes of the public not be bestowed and that it was some-g which must be earned.

he second speaker, N. L. Freeman, Secre-of the New York State Engineering rd of Examiners, gave an interesting account of the number registered and the requirements in the fields of nursing, law, medicine, and engineering. It was estimated that there are some 350,000 engineers in the United States of which 180,000 to 190,000 were registered. Of the several professions, from the time of entrance to the time of graduation the engineering schools had the highest mortality of 50 per cent, dental about 10 per cent, and medicine 5 per cent. The medical profession is the only one which has a clear-cut policy with licensing examinations which are an open book with options. In New York State, there are about 1,000 engineers licensed per year. Sixty-five to seventy-five per cent of the engineers pass their examinations as compared with 50 per cent of the applicants in law and 85 per cent in medicine.

In conclusion, the speaker explained that each of the professions has a pet grievance. In nursing, it is that more people try to tell the nurses how to run their profession. In law, it is that the type of man and his character is not as good as before the war. In dentistry, the dentists are concerned about the administration of penicillin. In medicine, there is concern about the high professional training required which is expensive with too much science and too little art. The speaker hoped that the panel would result in an increase in professional attitudes on the part of engineers.

The third speaker, K. B. McEachron, Jr., manager of the Technical Education Division, General Electric Company, represented the point of view of the electrical manufacturer. He explained that what industry looks for in the engineering graduate is the ability to get things done. Engineers have demonstrated that ability and for that reason R. H. Macy has hired engineers as buyers.

With reference to the industrial training program, the speaker explained that some 20 or 30 years ago men grew up with the industries, but today young engineers must acquire that experience and become familiar with the organization in a year or so. After training, they become members of the design group, development group, and so forth. With reference to the term "technician," the speaker preferred the term "engineers in training" for those pointed toward professional engineering.

In conclusion, the speaker felt particularly concerned about the tendency toward grouping among young people today rather than remaining as individuals on an individual responsibility basis with associates at the same level. The problem presented a serious threat which needed to be given careful consideration and an older respected group, such as the Institute, could help in the matter.

The fourth speaker, L. A. Russ, Director of Management Development of the Westinghouse Electric Corporation, analyzed what an engineer should do to develop his ability and what industry could do to assist him. As individuals, engineers are interested in knowing how one progresses in an organization. From a management development point of view, companies should determine exactly what their requirements are and what each position demands of a man; an inventory should be taken of the personnel; an appraisal of performance would not be complete without an interview. Then the company should activate a program of guided development on what it has found out in the preceding steps.

With respect to desirable attributes, is an employee interested in work or pay? Does he get along well with people? Does he co-operate with those above or below him and is he big enough to learn from his mistakes? Is he getting ready for a bigger job? In conclusion, the speaker stated that education is a journey and not a stopping point.

The last speaker on the panel, Professor C. L. Dawes, represented the educational point of view and explained the contributions of engineering education to the development of the professional man. He said that engineering education has a great responsibility because it is the first contact with the profession which the prospective engineer encounters and first impressions frequently are last-

Photograph courtesy *Electrical World*

The five speakers at the round-table panel are shown with P. F. O'Neill, the presiding officer. Left to right are: J. L. Haley, Mr. O'Neill, N. L. Freeman, L. A. Russ, K. B. McEachron, Jr., and C. L. Dawes

ing ones. Education is responsive to the rapid changes in industry during recent years. In the early days, a considerable proportion of the curriculum was devoted to shop work, mechanical drawing, rotating machinery, and engine parts with many specialized courses such as power plant design, storage batteries, electric railways, telephony, and machine design. New developments such as the automobile, airplane, servomechanisms, electronics developing into microwaves, radio, radar, and television required more training in fundamentals: mathematics, physics, chemistry, symmetrical components, and so forth. At the same time, there came the impact for more cultural courses: writing, speaking, economics, and the social studies.

The speaker expressed agreement with the general trend toward more emphasis on fundamentals with an increase in the cultural courses, leaving the specialized training to industry which it can do better than the schools. The curriculum is still crowded and the rate of training cannot be profitably intensified. Although a course on professional development might be desirable, the present crowded curriculum makes the addition of such a course impracticable.

Professor Dawes drew attention to the fact that students are surrounded by a professional atmosphere and a professional environment as members of the faculties take an active part in professional societies; also through the activities of the student branches, students participate in meetings, and read papers and the journals. Engineers are becoming more professionally minded.

In respect to the use of the term "technician" for the graduates of a 4-year engineering school, Professor Dawes did not agree. The duties of the technician are more or less skillful manipulations of a repetitive type and they do not contemplate extending the boundaries of a science by conducting research and by applications of scientific principles at a high intellectual level. In conclusion, Professor Dawes said that engineering education always has been and still is most responsive to the requirements of the profession and, as the profession raises its standards, the engineering schools are prepared to adopt their curricula and methods to meet them.

Responses to Questions. With regard to a question about the value of psychological testing, L. A. Russ explained that this was still in the experimental stage and that some runs on high executives have proved that they never would have been executives.

In response to another question as to why the professional engineer's license could not be granted with the engineering degree, Mr. Freeman explained that it was the feeling that the graduate did not have enough experience and that there were great differences among those who passed the examinations.

In response to the question as to whether the majority of engineers at Electronics Park were licensed, Mr. McEachron explained that many of the engineers there were young men and that licensing was not required by law. The Vice-President of Engineering in the General Electric Company has always urged that all men become licensed as soon as possible.

With reference to the importance of employing a licensed engineer, Mr. Haley stated that the possession of a license was a good indication of achievement.

In conclusion, the chairman of the meeting, P. F. O'Neill, stated that it would take time to acquaint the public with the accomplishments of the engineer but he hoped that meetings of this kind were a step in the right direction.

THE BANQUET

The feature of the banquet on Thursday evening was an address by A. C. Monteith, Vice-President in Charge of Engineering, Westinghouse Electric Corporation. The speaker analyzed the present manpower situation in respect to the number of graduates and the needs of industry, the present Senate bill *S1* in regard to draft deferment, the program of the Engineering Manpower Commission of Engineers Joint Council (EJC), and the steps being taken by Engineers' Council for Professional Development (ECPD) to help in the situation.

The speaker drew attention to an article in *Life* which illustrated that there had been more progress in the last 50 years than in the last 5,000. Attention was drawn to the tremendous increases in speed from the time of the Pony Express to modern jet engines. In 1900, there was $2^1/_2$ horsepower back of each worker whereas in 1950 this had been increased to $7^1/_2$ horsepower. This is equivalent to 375 slaves back of each worker. In India and China they have less than $^1/_2$ horsepower per worker. These achievements, as well as what will come out of atomic energy, will be accomplished by engineers. The next war will be a technical war. Mr. Monteith spoke of the decrease in the number of engineers to be graduated which will result in a deficiency of 40,000 by 1954, and that is providing the draft does not interfere. The deficiency must be made up with brain power and industrial production, which has been a point that the public does not understand; it is very important that Mrs. Jones understand that the engineer is just as important as the frontline man in modern struggle.

With regard to the Senate bill *S1*, the speaker was sorry to see that universal military training was going to be postponed for the present. While approaching a system of universal military training, deferments would be essential and the plan to defer 75,000 men a year by examination was a step in the right direction although a deferment of 125,000 would be much better. This deferment is absolutely essential in order to keep engineers graduating pending the change. Selective Service has deferred 5,257,000 men up to the present; the plan under discussion would defer less than 5 per cent. Mr. Monteith said there were a lot of forces opposed to good planning. It looked as though a committee would be formed in Washington to act in an advisory capacity and discuss with industry and the armed forces their requirements and advise the local draft boards on the matter of deferments. As about 25 per cent of the men in industry were in the Officers' Reserve, this pointed up the need to have a really united organization to act on the matter.

Mr. Monteith spoke of the work of the Engineering Manpower Commission of EJC which has developed a 3-pronged program to alert high schools and parents about the shortage of engineers, to alert industry, and to work with the government to place the facts in their hands prior to the preparation of manpower bills. EJC plans to hold a manpower convocation in Pittsburgh next fall to alert all the engineering societies so that the facts with respect to engineering manpower may be brought out. Speaking from an intimate knowledge as Chairman of the Committee on Professional Training of ECPD, Mr. Monteith referred to their 6-point program and the report "The First Five Years of Professional Development." He concluded that the engineering profession must foster individualism rather than collective security and that everything must be done for the young engineers so that they will have a professional pride and feeling which is an essential way to get good engineers and leaders in this country, and the survival of the country is dependent upon having good technical people.

President LeClair addressed the banquet and complimented J. D. Hershey, General Chairman, and members of the committee on the arrangements. H. H. Graley, Chairman of the Syracuse Section, extended a cordial welcome and thanked the members of the committee for the assistance rendered in connection with the meeting. G. M. Pollard acted as toastmaster and introduced the speakers.

TECHNICAL SESSIONS

In addition to the round-table panel on the development of the engineer as a professional man, six technical sessions were held. The papers in a symposium on street lighting represented the points of view of a utility, a wire manufacturer, and a fixture manufacturer. A session on air conditioning provided a panel presentation and discussion of the problems of power supply for packaged air-conditioning equipment from the viewpoint of the utilities, the motor manufacturer, and the air-conditioning manufacturer. In a session on power generation, information was presented on the installations of the Niagara Mohawk Power Corporation including the design features, initial operating experience, and electrical features of the Dunkirk Steam Station as well as the fourth 80,000-kw unit at the Oswego Steam Station. Papers in another session on power generation dealt with such problems as the use of preferred orientation stripped steel in turbine generator stators, the effect of unit size on steam-electric generating station design, and system economics of extra-high-voltage transmission.

Computing Devices. In a session on computing devices, with F. J. Maginnis presiding, four papers were presented. The first paper, by I. B. Johnson of the General Electric Company, dealt with transient analyzer applications to problems encountered on a rural distribution system such as voltage changes due to resistance welding loads, lightning-arrester performance simulation on a rural distribution system, switching transmission lines with regard to high-voltage charging current, and magnification of switching overvoltages in coupled oscillatory circuits. The field data on an actual system and the results obtained from the analyzer were in close relationship.

The second paper, presented by Charles Wayne, described the OARAC, the General Electric Company's Office of Air Research Automatic Computer. This is a new decimal machine using the 2-star-421 code and it is not purely a binary machine. Although relatively slow, the objective was to design

ral-purpose computer to solve any type
roblem that may arise. There are five
c operations and 17 built-in operations
a magnetic drum memory device built
at the 10,000-word storage capacity can
very easily doubled. Advantages are
of operation and ease of maintenance
a reduction of tube compliments to
00 tubes.

n the third paper presented, E. G. Keller
ne General Electric Company explained
problem of guided missile calculation
g the differential analyzer and the
ndant advantages.

he last paper, presented by R. Haber-
n of the General Electric Company,
t with some of the industrial applications
nternational Business Machines. Among
applications mentioned were the problem
abulation or classification, solution of
ltaneous linear algebraic equations,
nonic analysis, problems which are
ed by a step-by-step procedure, and
ellaneous cases which do not fit the fore-
g such as the determination of critical
ds of multishaft vibrations in turbine
erators.

lectronics and Communications. The session
lectronics and communications was held
he Electronics Park auditorium with E.
Kenefake presiding.

n a paper on "Local Wire Video Tele-
on Networks," C. N. Nebel of the Bell
ephone Laboratories, Inc., described the
elopment of a new local video distribution
em which provides equalization and
plification of signals transmitted over
s between television studios, transmitters,
xial cables, and microwave networks (*EE,
'51, pp 130–5*).

"New Carrier-Current Frequency-
t System for Use With Differential Pro-
ion of Transformer Banks" was de-
bed by R. W. Beckwith of the General
ctric Company. Crystal-controlled fre-
ncy shift techniques are used to provide
h-speed (2-cycle) transfer tripping with
rance against undesired tripping due to
combination of power failure, compo-
t failure, switching, or other influencing
ors. Frequency modulation was em-
ed for the transmission of control im-
es. A degree of reliability has been pro-
d which is comparable to the use of a
h-side circuit breaker. In discussion of
system, I. D. Perry of the Public Service
ctric and Gas Company explained that on
Kearney-Bergen Line, frequency modu-
on was selected and two channels are used
ause a broadcast station was on the same
uency and Fort Monmouth had advised
they would use any frequency. Trip-
g was undesired when the blocking signal
out and radiation of the continuous
ier is at the same level as the number of
phone lines throughout the country.
F. Kennedy reported that several other
panies have had this same difficulty, and
wire circuits do not seem to have the
ability required for carrier.

he subject of "Remote Control by Tones"
discussed by J. L. Hayden of the General
ctric Company. Various factors leading
o the selection of a selective amplifier or
iving device, and a tone generator which
sists of a selective amplifier similar to the
iving device, were described. The same
work and similar components are used in
tone generator and the selective amplifier.
These two basic circuits formed the basis of a variety of selective signalling applications, selective dispatching, a selective calling system, a selective dispatching system, using a tone for the call-back, and a remote control system using the same circuits but applied so that they can control relays.

The last paper, which was presented by F. C. Krings of the General Electric Company, reviewed the "Factors in the Choice of Microwave or Carrier Channels for Power System Operation and Dispatching." The large number of channels between two points free from man-made static makes microwave equipment attractive. It also can be directed into narrow beams, thereby reducing the possibility of interference between other nearby microwave high-frequency channels, and the system is physically separated from the power transmission circuit. On the other hand, the author pointed out the disadvantages of putting a large number of channels on one microwave link, repeater stations at frequent intervals with the attendant problems of power supply, and emergency power supply as well as maintenance. The advantages and disadvantages of carrier were also reviewed together with an analysis of the economic factors of the two systems.

STUDENT BRANCH CHAIRMEN AND COUNSELORS LUNCHEON

Following the luncheon a brief business meeting took place with H. F. Cooke presiding. Minutes of the last meeting held in Providence, R. I., were approved as distributed.

Ways in which to interest Students in Branch activities were considered. A study of the possibilities of a color film for this purpose was found to be too expensive. Other methods were suggested such as an illustrated brochure or pamphlet and a section each month in *Electrical Engineering.* In response to a question, the editor explained that in conversations with many Students and Counselors, preference had been expressed to have the Branch Activities reported together with the other news on Institute Activities rather than in a separate section. Also, with a circulation of over 50,000 copies, the publication of a pamphlet might be less expensive than pages in the magazine. Attention was called to unillustrated folders available at headquarters on "Student Membership and Branch Activities."

The chairman reported that the District Executive Committee was anxious to get as large a student enrollment as possible, and in the case of joint Branches the question was raised as to whether pressure was applied to get the Students to enroll in the AIEE or the Institute of Radio Engineers. Professors Northrup and Tarboux explained that the important thing was to get the students to join a society.

Nominations for the chairman of the District Committee on Student Activities were placed in order and Prof. W. H. Erickson of Cornell University was appointed. Although Binghamton, where the next North Eastern District Meeting will be held, is 50 miles away from Ithaca, it will be possible to arrange some interesting trips.

With regard to questions about interpreting the rules for judging Branch paper prizes, Chairman Cooke suggested that Professors Tarboux and Erickson should investigate and clarify the interpretation of the rules and send the information to all Branches.

Preceding the luncheon two sessions were held in which a total of 17 undergraduate and graduate papers were presented. The winners of the prize awards were announced in the June *Electrical Engineering*, page 551.

A vote of thanks was extended to the host chairman for all he had done in connection with the meeting and other activities.

LADIES' PROGRAM

The ladies were kept busy with the banquet, luncheons, a review of a recent New York play by Mary Aldrich Jones, a trip to the Onondaga Pottery Company's plant, and bridge at the Bellevue Country Club. Shopping tours and visits to points of interest were arranged on request.

INSPECTION TRIPS

One of the features of the meeting was a trip to Electronics Park where a tour was made through the metal-backed picture tube plant and research work on color television was demonstrated.

Another trip was arranged to the Engineering School of Syracuse University, which has moved to new quarters with complete laboratory equipment and facilities.

COMMITTEE

The chairmen of the 1951 North Eastern District Committee which made the arrangements were as follows: J. D. Hershey, *General Chairman;* J. H. McClennan, *Finance;* M. H. Pratt, *Technical Program;* George Pring, *Publicity;* H. F. Cooke, *Student*; Dave Williams, *Hotels;* C. E. H. Von Sothen, *Registration;* Paul O'Neill, *Entertainment;* L. M. Moore, *Trips and Transportation;* B. T. Cole, *Social Hour;* and Mrs. Paul O'Neill, *Ladies' Program.*

Regular Meeting of AIEE Board of Directors Held in Miami Beach

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held in the MacFadden Deauville Hotel, Miami Beach, Fla., on April 12, 1951.

The minutes of the meeting of the Board of Directors held on January 25, 1951, were approved.

The following actions of the Executive Committee on membership applications, upon recommendation of the Board of examiners, were reported and confirmed: As of February 23, 1951: 23 applicants elected and 2 applicants re-elected to grade of Member; 108 applicants elected and 5 applicants re-elected to grade of Associate; 243 Student members enrolled. As of March 22, 1951: 21 applicants transferred and 1 Fellow reinstated to grade of Fellow; 38 applicants transferred and 21 applicants

elected to grade of Member; 101 applicants elected and 9 applicants re-elected to grade of Associate; 161 Student members enrolled.

Recommendations adopted by the Board of Examiners at meetings on February 15 and March 15, 1951, were reported and approved. The following actions were taken upon recommendation of the Board of Examiners: 20 applicants were transferred to grade of Fellow; 41 applicants were transferred to grade of Member; 122 applicants were elected to grade of Associate; 3,119 Student members whose terms expire April 30, 1951, were elected to the grade of Associate; and 161 Student members were enrolled.

The following Local Honorary Secretaries of the Institute were appointed: For Brazil: W. L. Simpson, Sao Paulo Tramway Light and Power Company, Sao Paulo, Brazil; For Japan: Stetfan Tanabe, Saito Industrial Company, Ltd., and Yokohama Foreign Trade Institute, Tokyo, Japan.

FINANCES

The Board approved expenditures reported by Chairman W. J. Barrett of the Finance Committee, as follows: February, $78,349.86; March, $69,947.92.

A statement of income and expenditures thus far in this appropriation year, compared with the figures for the same period of last year, was presented and indicated that both income and expenses were closely in line with the situation of last year.

The following resolution was adopted upon recommendation of the Finance Committee: "Resolved: That the names of members in arrears on May 1, 1951, for dues for the fiscal year which began May 1, 1950, be removed from the active membership list, as required by the Institute By-laws, and that the time for payment of such dues be extended until further action by the Board of Directors."

Authorization was given for the usual joint conference on Student activities of Districts 8 and 9 to be held in Portland, Oreg., during the 1951 Pacific General Meeting, August 20–23.

APPOINTMENTS

The Board approved the appointment by the President of the following Committee of Tellers to count and report on the ballots cast in the election of Institute officers and the ballots on the proposed amendments to the Constitution: Delavan Halloran (Chairman), J. L. Bialous, Warren H. Bliss, J. J. Duncan, Arthur Hauspurg, J. T. O'Connell, A. L. Swensk.

Joseph W. Barker was nominated for re-election by the Board of Trustees of United Engineering Trustees, Inc., as a member of the Engineering Foundation Board, representing the AIEE, for the 4-year term beginning in October 1951.

Walter J. Barrett was appointed a representative of the Institute on the Board of Trustees of United Engineering Trustees, Inc., for the remainder of J. F. Fairman's term expiring in October 1951, and for a 4-year term beginning at that time.

The President was authorized to appoint a representative of the Institute on the Hoover Medal Board of Award for the term of six years, to succeed Dr. Harold S. Osborne at the expiration of his term in 1951. (T. G. LeClair was appointed.) Walter J. Barrett was appointed alternate for J. G. Tarboux to attend the annual meeting of the Hoover Medal Board of Award on May 1, 1951.

W. L. Everitt was appointed an AIEE representative on the Washington Award Commission for the term of two years beginning June 1, 1951.

The Board approved a questionnaire to the membership prepared by the Publication Committee in connection with its study of the desirability of issuing five technical division publications, and made an appropriation for the printing and mailing of the questionnaire and the postage on copies returned by the members.

STANDARDS COMMITTEE

Approval was given to the acceptance by the Standards Committee of an invitation from the American Standards Association (ASA) to act as sponsor of the ASA Sectional Committee on Electric Equipment in Metal Mines, *M24*.

The following appointments of AIEE representatives were reported by the Standards Committee:

- Electrical Standards Committee, ASA: C. M. Gilt as alternate to succeed E. B. Paxton.
- ASA Drawings and Symbols Correlating Committee: H. P. Westman, representative.
- Sectional Committee *M2* "Electric Equipment in Coal Mines": J. Z. Linsenmeyer, alternate.
- Sectional Committee *Z32* "Graphical Symbols": A. F. Pomeroy, chairman of reorganized sectional committee.
- Sectional Committee *A13* "Identification of Piping Systems": H. R. Harris, representative.
- Sectional Committee *C61* "Electric and Magnetic Magnitudes and Units": J. B. Russell, representative.
- Sectional Committee *B30* "Cranes, Derricks and Hoists": Samuel Rifkin, representative.

Report was made of the approval by the Standards Committee of the following Standards:

- Code for Protection Against Lightning, *C5*
- Proposed Revision of Table I of *C50* "Rotating Machinery"
- Master Test Code for Temperature Measurement, AIEE *551*
- Preferred Standards for Large 3,600-Rpm 3-Phase 60-Cycle Condensing Steam Turbine Generators, AIEE *601* and *602* (revision)
- Recommended Specification for Speed Governing of Hydraulic Turbines, AIEE *605*
- Proposed Test Code for Aircraft Interrupting Devices, AIEE *801*
- Application Guide for Grounding of Instrument Transformer Secondary Circuits and Cases, AIEE *52*

A proposal of the American Standards Association for the establishment of a "Standards Medal" to be "awarded annually to an individual who has made substantial contributions to the field of standardization or who has taken a definite leadership in the standardization movement" was referred to the Standards Committee with power.

Upon recommendation of the Technical Advisory Committee, the Board authorized the merger of the Committee on Therapeutics and the Joint Subcommittee on Electrical Aids to Medicine to form a new "Committee on Electrical Techniques in Medicine and Biology," with the following scope of activity: "The treatment of all matters in which the dominant factors are electrical techniques that are used in medical and biological research, diagnosis, and therapeutics. The committee is concerned particularly with the intercommunication of problems, and their solutions, between electrical engineers on the one hand and physicians and biologists on the other. In planning papers and programs to this end, the committee will work jointly with the other interested AIEE committees and may enlist the aid of consultants in the field of biology and medicine."

APPOINTMENTS

Secretary Henline was authorized to attend the 15th Conference of the Council of Engineering Society Secretaries to be held in Rochester, N. Y., June 22–23, 1951.

The President and the Secretary were authorized to attend the Conference of Representatives of Engineering Societies of Western Europe and the United States of America to be held at The Hague, Holland, September 17–21, 1951, and funds were appropriated to cover their expenses.

The President was empowered to act on an invitation from Millard Caldwell, Administrator, Federal Civil Defense Administration, to send five representatives to an important Civil Defense Conference to be held in Washington, D. C., May 7 and 8. President LeClair appointed E. W. Davis, J. F. Fairman, A. H. Kehoe, Frank B. Crider (Chairman, Washington Section), and John W. Gore (Chairman, Maryland Section).

An invitation from the Benjamin Franklin Committee of the National Society of the Sons of the American Revolution "to take a lead in 1952 in commemorating the flying in 1752 by Benjamin Franklin of the historic kite which had the key to electricity" was referred to the Philadelphia Section.

The President was authorized to appoint an AIEE representative on the recently authorized Student Development Committee of the Engineers' Council for Professional Development. This committee will "operate in the area between the Guidance Committee, covering the pre-college field, and the Training Committee, which operates in the post-college field."

Upon invitation to meet in Cleveland during the Fall General Meeting, the Board voted to hold its October meeting in Cleveland on Thursday, October 25, 1951. The date of the August Board meeting, previously scheduled to be held in Portland, Oreg., during the Pacific General Meeting, was set as Thursday, August 23, 1951.

Other matters were discussed.

Present at the meeting were: *President* T. G. LeClair; *Past Presidents* J. F. Fairman and Everett S. Lee; *Vice-Presidents* W. C. DuVall, A. H. Frampton, R. A. Hopkins, J. A. McDonald, J. R. North, C. S. Purnell, W. J. Seeley, J. G. Tarboux, C. G. Veinott; *Directors* W. J. Barrett, E. W. Davis, W. L. Everitt, C. W. Fick, N. B. Hinson, M. D. Hooven, F. O. McMillan, Elgin B. Robertson, Victor Siegfried; *Secretary* H. H. Henline.

trict 2 Branch Prize Paper ompetition Held at Villanova

ne Middle Eastern District (Number 2) its District Branch Prize Paper Comion for 1951 at Villanova, Pa., on April 8. Villanova College acted as host. en District 2 Branch Prize Paper ners participated in the competition. vard R. Stillwell, University of Pittsh, won first prize for his paper "Reing Conductometers for Electrolytes," iving a cash prize of $25.00 and a Create of Award. Second prize was rded to Henry A. Lee, Lafayette College, third prize to Fritz Friedlaender, negie Institute of Technology. Viceident C. G. Veinott made the prestion.

homas J. Burke of the Villanova College lent Branch headed the committee in ge of the contest meetings. He had the ve support of Prof. John B. Clothier, nselor, Charles F. Devenny, Chairman, other members of the Student Branch the faculty.

egistration began at 10:00 a.m. Friday. informal inspection of the Naval Reserve cers Training Corps training facilities arranged for the early arrivals. The session began at 1:30 p.m. Contestants e introduced by Mr. Burke. Presentas were limited to 15 minutes with 4 utes allowed for discussion. Seven ers were given in the first session.

dinner for the contestants, Counselors, ges, members of the Philadelphia Section, lty, and students was held at the Philahia Engineers' Club. Guests included . F. X. N. McGuire, President of Villaa College, Rev. Thomas A. Burke, Rev. n A. Klekotka, and Dean J. Stanley rehouse, all of the college, while the ladelphia Section delegation was headed Chairman S. R. Warren. Certificates Award were presented to each Branch ze Paper Contest winner by District retary Dynes.

he eight remaining papers were given urday morning. Announcement of the rds was made by Prof. J. T. Jonas, fessor of English at Villanova, acting as irman of the Judging Committee. The ze Paper Judging Committee consisted of liam G. Amey, Henry V. Davis, and an H. Kidder, all of the Philadelphia tion, and Professor Jonas.

he Villanova College Branch had also vided a $2.50 prize for each session for best question asked in discussion. The ges named J. J. Kleschick and James t, both of Villanova, as the winners. ards were presented by Secretary Dynes. aturday afternoon all those attending meeting were invited to a baseball game ween the Quantico Marines and lanova.

he 15 Branch Prize Paper winners who k part in the competition were:

t Prize: Howard R. Stillwell, University Pittsburgh, "Recording Conductometers Electrolytes"

nd Prize: Henry A. Lee, Lafayette Col-e, "Direct Method of Determining Sag l Tension in Short Wire Spans"

rd Prize: Fritz Friedlaender, Carnegie titute of Technology, "From Symbolism Circuits"

Delegates, Counselors, and students are shown at Villanova College during the District 2 Branch Prize Paper competition. Left to right in the front row are: Father Klekotka, W. G. Amey, C. G. Veinott, W. A. Dynes, A. H. Kidder, Prof. J. T. Jonas, H. V. Davis, and Dean J. S. Morehouse

George R. Bechtel, University of Akron, "Liquid Slip Regulator"

Joseph C. Modie, Case Institute of Technology, "The Theory and Application of the Kerr Cell"

Richard J. Spady, Drexel Institute of Technology, "The Fundamental Principals of the Oil Circuit Breaker"

Ray V. Jaracz, Fenn College, "Testing TV and FM Antennas"

W. A. Wooldridge, George Washington University, "Modern Oil-Filled High Voltage Bushings"

Elmus J. Ball, Howard University, "Use of Turning Screws and Window Apertures as Impedance Watching Devices"

William F. List, Johns Hopkins University, "Audio Frequency Voltage Supply for Dielectric Studies and Bridge Measurements"

James Palz, Ohio Northern University, "Electron Tube Failures in Industrial Applications"

Richard Beedy, Ohio University, "Frequency Measurement—A Review of the Common Methods of Measuring Frequency and of the New Sliding Harmonic Type of Measurement"

J. F. Swingle, University of Pennsylvania, "A Constant Current Source for Nuclear Particle Accelerators and Charged Particle Mass Spectrographs"

John M. Tomlinson, Pennsylvania State College, "The Design of a Computer Utilizing Symbolic Logic"

Thomas W. Morling, Villanova College, "The Responsibility of the Engineer in the Community"

Chicago Section Holds Student Branch Prize Paper Competition

A prize paper contest for Chicago area student members of AIEE, sponsored by the Chicago Section, was held on April 24 and 25. Separate contests were held for the graduate and undergraduate students at both Northwestern Technological Institute and Illinois Institute of Technology.

The prizes in all contests were $15 for first, $10 for second, and $5 for third, plus an AIEE certificate. At Illinois, there were three undergraduate contestants and nine graduate. At Northwestern there were three each. The papers were presented orally. The prizes were distributed at the section general meeting Thursday, April 26.

The twelve winning contestants were invited to the pre-meeting dinner to meet Mr. H. N. Muller, the speaker of the evening.

The list of prize winners follows:

Illinois Institute of Technology

Undergraduate

First Prize: John Wilder, "Cathode Ray Oscilloscopes as an Industrial Measuring Tool"

Second Prize: R. C. Kuhn, "Induction Heating Coils"

Third Prize: H. J. Hummel, "Negative Capacity Amplifiers"

Graduate

First Prize: G. T. Flesher, "Linear Accelerators"

Second Prize: A. J. Wood, "Overvoltages in High Voltage Current Transformers"

Third Prize: L. J. Stratton, "Grounding Mats for High Voltage Stations"

Northwestern Technological Institute

Undergraduate

First Prize: George Mack, "Stability of Non-Linear Systems"

Second Prize: G. Douglas Moeller, "Carrier Telephone Systems"

Third Prize: Ward Montgomery, "Amateur Radio in Civilian Defense"

Graduate

First Prize: James Van Ness, An "Analogue of a Synchronous Machine for Use with a Network Analyzer in Transient Stability Studies"

Second Prize: Richard Andeen, "The Simulation of a Large Capacitor by a Shunt D-C Motor"

Third Prize: Joseph Naines, A "Non-Linear Differential Difference Equation"

The judges were: *At Northwestern*, J. L. Wysong, Public Service Company of Northern Illinois; M. V. Maxwell, Westinghouse Electric Company; and E. G. Norell, Sargeant and Lundy. *At Illinois Tech*, C. C. Cole, Western Electric Company; S. C. Killian, Delta Star Electric Company; and D. K. Chinlund, Illinois Bell Telephone Company.

Talent Search for Authors Held

A talent search for authors instead of a prize paper contest was held this year by the Sharon, Pa., Section, and the papers were presented at the Annual Prize Papers Meeting on May 16. Copies of all papers were made available to members in advance of the meeting, and all authors were invited to the Author's Dinner preceding the Section Meeting. The direct expense for duplicating and distributing papers and entertaining the authors was less than the total prize money previously awarded. More than one member in 20 became an author, and over twice the previous average number of papers were submitted. Three papers, selected by member ballot, were presented at the meeting, but all papers were presented by title and were open for discussion by the members. All those in the photograph are authors except H. B. West, Chairman of the Entertainment Committee; John H. Chiles, Jr., Dinner Sponsor; and A. J. Maslin, Chairman of the AIEE Sharon Section. Seated, left to right, are: H. L. Cole, H. B. West, L. B. Rademacher, W. L. McKeithan, A. J. Maslin, and E. C. Wentz. Standing, left to right, are: L. E. Sauer, G. Stein, John H. Chiles, Jr., R. L. Bean, A. G. Feeley, T. G. Gerwing, H. L. Prescott, Albert Lucic, R. M. Ray, and F. B. Colby

1951 Fall General Meeting to Be Held in Cleveland

This year the AIEE Fall General Meeting will be held in Cleveland at the Hotel Cleveland, October 22 through 26.

Located in a highly diversified industrial area, Cleveland offers attractions to the many segments of interest among the Institute membership. Industrial production of the area includes the manufacture of steel, heavy machinery, mechanical parts, electric machinery, electronic and control equipment, transportation equipment, rubber, chemicals, petroleum products, and many others. It is also the center for a wide variety of research and educational facilities, including Western Reserve University, Case Institute of Technology, National Advisory Council for Aeronautics Lewis Flight Propulsion Laboratory, John Carroll University, Baldwin-Wallace College, and a number of private and industrial research organizations.

Among the inspection trips available to AIEE members and guests will be visits to the Republic Steel Company's 98-inch strip mill, Lincoln Electric's radically new plant, the Goodyear Rubber Company at Akron, General Electric's Nela Park, and others. Many of the principles and equipment discussed at the technical sessions may be observed in actual operation at the inspection trip sites.

For the lady guests at the meeting, a full and varied program has been arranged. Some of the activities will be a fashion show, a trip to the Cleveland Museum of Art, a trip to the country and an antique display, luncheons, parties, and teas. Extra hostesses will help make the lady guests' visit interesting and comfortable.

Entertainment features for the Fall General Meeting have been carefully selected and planned for wide appeal to the Institute members and guests. A smoker, a dinner dance, and a theater party at Cleveland's unique Playhouse Arena Theater are among the attractions that will climax the various days' activities of a pleasant and worthwhile week in Cleveland.

The Terminal Tower is shown with the Hotel Cleveland, headquarters of the Fall General Meeting, at the right

West Virginia Branch Dinner Honors Graduating Seniors

The West Virginia University student chapter of the AIEE gave a spaghetti dinner on May 9 in honor of the graduating seniors. Prof. E. L. Keener acted as toastmaster for the dinner.

Joseph V. Tassone, president of the General Engineering Society of the University, presented a speech on the responsibilities of engineers to fields other than engineering. Prof. E. C. Dubbe announced that James M. Buchanan had been chosen to receive the annual AIEE award to the member who is outstanding in work done for the organization during the past year. Mr. Buchanan, a graduating senior in electrical engineering, has been president of the local chapter during the 1950–1951 school year. Not only has he been active in all AIEE functions, but also in Tau Beta Pi and Eta Kappa Nu, of which he is a member. He is largely responsible for the new, improved constitution adopted by the local organization this spring.

Mr. Buchanan gave a short farewell speech as the retiring president and Robert C. Johnston, the new president, gave an acceptance speech for his new office. The other new officers, who were presented at the dinner, are: Eugene W. Conley, Vice-President; Robert B. Hunsaker, Treasurer; James E. Harris, Secretary, AIEE; and A. L. Riggs, Secretary, Institute of Radio Engineers.

Attending the dinner were: Prof. C. B. Seibert, Prof. M. M. Peterson, Prof. E. L. Keener, Prof. E. C. Dubbe, Warren B. Moore, James M. Buchanan, Robert C. Johnston, D. N. Horner, B. K. Fuller, R. D. Richards, Roscoe W. Ward, John W. Bail, Charles M. Minke, Harold E. Knapp, Robert B. Hunsaker, James E. Harris, Dayton L. Jackson, Michael Malich, J. P. Stillwell, Paul C. Cooper, Otis J. Graham, Eugene W. Conley, and William E. Brown.

Additional Names Announced to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and paid dues for 30 years. A list of those who have become Members for Life during the preceding year is published annually in *Electrical Engineering*. Institute members enrolled as Members for Life as of May 1, 1951, are

Albrecht, H. C.
Baily, P.
Baker, J. S.
Baker, P. W.
Bartlett, L.
Belt, J. H.
Bergstrom, C. O.
Bills, F. B.
Blackmore, C. T.
Bliem, H. M.
Board, V. L.
Boegehold, E. S.
Bradley, H. L.
Branson, E. H.
Bretch, E.
Broadbent, W. W.
Buchanan, W. B.
Bunch, C. H.
Burgi, H., Jr.
Burgner, H. T.
Burr, H. B.
Busby, J. H.
Calman, C. G.
Camp, W. E.

Johnston, R. A.
Jones, M. L.
Kallevang, E. J.
Kinard, C. A.
King, C. F., Jr.
Klumb, H. J.
Koberg-Bolandi, M.
Koiner, J. S.
Kun, E.
Lamar, R. W.
Lopez, E. F.
Luft, O. L.
Manbeck, P. D.
Marion, J. F.
Markle, E. W.
McAlpine, D. D.
Metcalfe, V. E.
Milne, W. G.
Murphy, W.
Murray, J. B.
Neff, G. C.
Ober, D. C.
Obermaier, J. A.
Oehrig, H. B.

y, A. M.
on, J. H.
r, T.
ent, M. F.
er, A. B.
ger, F. L.
enden, E. C.
s, H. L.
o, J. P.
ow, L. H.
, O.
on, T. E.
nty, B. F.
nson, N. S.
rd, E. W.
e, A. J.
ky, F.
rds, G. D.
an, J. D.
nschied, L.
s, P. H.
y, W. S., Jr.
n, P. R.
er, W. D.
klin, R. E.
s, J. O.
C. M.
s, C. D.
rd, W. S.
ho, A. P.
on, H. E.
d, L. B.
son, A. C.
er, F. W.
es, F. A.
C. L.
y, H. S.
H. S.
R. H.
ley, R. V. L.
mann, R. R.
t, E. S.
E. E.
nes, E. L.
J. I.
ter, T. M.
C. E.
G. W.
ous, R. F.

Oliver, J. M.
Palmer, S. G.
Parkinson, R. W.
Perry, T.
Phelps, H. S.
Pierce, H. J.
Plimpton, C. G.
Pratt, H.
Ramey, B. B.
Ready, W. A.
Reeve, C. T.
Rich, A. R.
Richmond, A. L.
Rickard, E. B.
Rost, H. F.
Ruttiman, A.
Sebast, F. M.
Segel, H.
Shanklin, G. B.
Shuler, W., Jr.
Sibley, E. D.
Simonson, G. M.
Small, W. G.
Snyder, C. C.
Sparling, E. C.
Spencer, C. G.
Spengler, W. D.
Sprague, R. V.
Spray, L. W.
Stewart, C. R.
Stiner, H. W.
Stoddard, A. D.
Stottler, M. W.
Tappan, F. G.
Trompen, N. J.
Umansky, L. A.
Van Steenburgh, W. R.
Vinet, E.
Walton, E. R.
Waterman, C. C.
Waters, W. A.
Weeks, J. R., Jr.
Weiser, R. G.
Wheatlake, B. C. J.
Williams, A. L.
Wilson, J. M.
Witzel, E. R.
Wolf, K.
Wood, H. B.

Yoder, C. P.

51–52 Fortescue Fellowship Awarded to C. J. Baldwin, Jr.

he Charles LeGeyt Fortescue Fellowship nmittee of the Institute has awarded a owship for graduate study in electrical ineering to Clarence J. Baldwin, Jr., is expected to receive the degree of helor of Science in Electrical Engineering the University of Texas in June 1951. will engage in graduate study at that itution during the year 1951–52.

Ir. Baldwin is a member of Eta Kappa and Tau Beta Pi, and is Cadet Colonel nmanding the Reserve Officers Training ps unit at the University of Texas. He past Vice-President and past Treasurer the Eta Kappa Nu chapter, and has aged in numerous other student activities.

he fellowship was established through a t fund set up by the Westinghouse ctric Corporation in recognition of Mr. tescue's valuable contributions to the tric power industry, and is awarded by ommittee of the AIEE.

EE Receives Certificate of Co-operation from ECA

. Certificate of Co-operation was pre- ted recently to the AIEE by the Economic operation Administration (ECA) for aid given by the Institute in the Marshall n Technical Assistance Program. The ificate was given in recognition of the E's assistance and co-operation in ring its technical knowledge with visiting ign groups, which knowledge has con- uted directly to the economic recovery of tern Europe and its defense potential the future.

Special Session of Los Angeles Section Honors Dr. Sorenson

A special meeting for Dr. Royal W. Sorensen, Professor of Electrical Engineering, Emeritus, California Institute of Technology, and a past President of AIEE, was held for the presentation of a certificate of honorary membership in the Institute of Electrical Engineers of Japan (IEEJ). The meeting was arranged and brought to order by Mr. E. K. Sadler, Vice-Chairman. After a dinner in the Athenaeum, Mr. T. W. Blakeslee, District 8 Secretary, acted as master of ceremonies and introduced the guests from Japan.

The certificate was presented to Doctor Sorensen by Dr. Matsujiro Oyama, Dean of the Faculty of Engineering at Tokyo University and past President of the IEEJ. Doctor Sorensen, who was recommended for the honor by AIEE, is one of two living honorary members of the organization. Doctor Sorensen, in thanking Doctor Oyama for the certificate, spoke of his experiences during his trip to Japan.

Mr. Clarence Winder, member of the City of Pasadena Board of Directors, presented Doctor Oyama with a key to the city of Pasadena.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Division

Committee on Television and Aural Broadcasting Systems (*J. B. Coleman, Chairman; I. J. Kaar, Vice-Chairman; W. L. Lawrence, Secretary*). The committee has continued active work arranging for technical papers in the field of broadcasting. Work is in progress for a session on broadcasting at the Fall General Meeting, and four interesting papers are in prospect. No work on standardization is contemplated at this time.

General Applications Division

Committee on Land Transportation (*H. F. Brown, Chairman; L. W. Birch, Vice-Chairman; R. L. Kimball, Secretary*). This committee has been very active during the year in keeping the Institute informed of the progress and new developments in Land Transportation. During a committee meeting held in Philadelphia, the members had the opportunity of inspecting the "Ignitron-rectifier" car with d-c motors in use on the Pennsylvania Railroad a-c electrification, and the electric Train Performance Calculator which had recently been placed in service on that railroad. New a-c multiple-unit car equipment recently acquired by the Reading Railroad also was inspected.

Power Division

Committee on Substations (*R. C. Ericson, Chairman; K. L. Wheeler, Vice-Chairman; N. G. Larson, Secretary*). This committee is forming a new subcommittee, to become effective at the beginning of the next administrative year, dealing with mechanical rectifiers. It would deal initially with standards for nomenclature, circuitry, equipment, and technical papers.

Possible new projects for study are: 1. Noise Level of Transformers; 2. Economic Selection of Transformers; 3. Application of Supervisory Equipment and Reclosing Relays; 4. Plants versus Pasted Plate Storage Batteries for Station Use; Comparison of Selenium Copper Oxide, Electronic, and Motor Generator Sets for Charging Storage Batteries; 5. Recommended Minimum Clearances; 6. Use of Small Reactors; 7. Possible Project—High-Voltage Fuse Design and Characteristics for All Types of Bus Faults, Outdoor Substations; and 8. Working Group on 1-Line Diagrams.

Committee on Transmission and Distribution (*I. W. Gross, Chairman; S. B. Crary, Vice-Chairman; R. E. Pierce, Secretary*). The committee held a meeting during the Winter General Meeting. The subcommittees have been quite active and reported as follows:

Lightning and Insulator Subcommittee (J. T. Lusignan, Chairman). The subcommittee met during the Winter General Meeting and reported that the sale of the Lightning Reference Bibliography (*S-37*), which was prepared by the subcommittee in 1950, has been quite low. Copies are available at AIEE Headquarters at 70¢ (35¢ to AIEE members). The subcommittee also discussed the subject of operating records of expulsion tubes on transmission lines (22–69 kv).

Capacitor Subcommittee (F. V. Smith, Chairman). A group in this subcommittee is giving consideration to the voltages that capacitors can withstand from short times to long times. A bibliography on capacitors has been submitted to this subcommittee.

Distribution Subcommittee (T. J. Brosnan, Chairman). The subcommittee has been working jointly with the Relay Committee, and also with the Edison Electric Institute Transmission and Distribution Committee on co-ordination of protection and construction of distribution circuits.

General Systems Subcommittee (R. L. Witzke, Chairman). This subcommittee has been working on two projects: 1. Recovery voltage characteristics of distribution circuits. A report is being prepared to give the basis for determining recovery voltage characteristics, if circuit constants are known. 2. Outage records of transmission circuits. A survey is being made of line outages 100 kv and above. Data have been received from over 60 operating companies and have been coded and put on International Business Machine cards. The data cover 34,000 miles of line, 237,000 mile-years of experience, and 22,000 outages. Further consideration is being given to the matter of obtaining statistical data before a decision is reached on the question.

Towers, Poles and Conductors Subcommittee (A. E. Davison, Chairman). This subcommittee held a meeting on January 24. Some of the topics being considered by the subcommittee are: limiting overload a-c currents for electric conductors; insulated aluminum conductors using neoprene and other coatings; multiple conductors, wood versus steel supports, and so forth.

The Committee on Transmission and Distribution will meet during the Summer General Meeting.

Science and Electronics Division

Committee on Electronics (*W. G. Dow, Chairman; J. T. Thwaites, Vice-Chairman (East); A. M. Zarem, Vice-Chairman (West); E. M. Boone, Secretary*). The committee has decided that it is not desirable to split the committee and separate the electron tube subcommittee activity because of the very great profit that accrues both to the electron tube group and the circuit activities represented in the committee by their mutual association and contact. It seems apparent that the committee represents not only activities in special fields requiring specialized talent but also serves as a valuable forum for the exchange of opinions and judgments as to the proper future program of electronics' activities within AIEE.

The committee is continuing to support specialized conferences in specific areas and plans the following conferences: Conference on Electron Tubes for Power Conversion in Industrial Control Equipment (location not yet decided); Annual Electron Devices Conference, held in June 1951 at the University of New Hampshire; Conference on Electronic Instrumentation in Nucleonics and Medicine in December 1951.

AIEE PERSONALITIES.....

L. N. McClellan (A '14, F '38, Member for Life), chief engineer, United States Bureau of Reclamation, Denver, Colo., was the recipient recently of the Gold Medal Award, the highest honor that can be bestowed by the Colorado Engineering Council. The Gold Medal Award, which has been made only four times previously in 25 years, is given for "Distinguished Engineering Services." Mr. McClellan was graduated from the University of Southern California in 1911 with a bachelor of science degree in electrical engineering and received the honorary degree of doctor of engineering from the University of Colorado in 1949. Following graduation he began his service

L. N. McClellan

with the Bureau of Reclamation and successively held the positions of chief electrical engineer, assistant chief engineer, and in 1948 he was appointed chief engineer of the Bureau of Reclamation and director of design and construction. Under his direction many of the great power facilities of the Bureau were conceived and designed. Mr. McClellan is the author of many technical articles on power developments and other phases of reclamation projects which have appeared in various technical journals. He is a member of Tau Beta Pi and Sigma Xi and is a member of the National Engineers Committee of the Engineers Joint Council. Mr. McClellan has actively served the Institute as Vice-President, District 6 (1937–39), and on the following committees: Power Transmission and Distribution (1933–36); Automatic Stations (1937–39); and Applications to Mining Work (1937–38).

M. J. Kelly (M '26, F '31), Executive Vice-President, Bell Telephone Laboratories, Inc., New York, N. Y., has been elected President of the organization. Born in Princeton, Mo., in 1894, he was graduated from the Missouri School of Mines and Metallurgy in 1914 and received his master's degree from the University of Kentucky in 1915. He received his doctorate from the University of Chicago in 1918 and then joined the engineering staff of the Western

M. J. Kelly

Electric Company which was subsequently incorporated as Bell Telephone Laboratories. Doctor Kelly served as director of vacuum-tube development from 1928 to 1934 and as development director of transmission instruments and electronics until 1936, when he was appointed director of research. In 1944 he became Executive Vice-President. During World War II Doctor Kelly directed many of the war activities at the Laboratories, and for the past year he has served the Department of the Air Force in an advisory capacity to assist in the organization of research and development in that department. Doctor Kelly is an active member of the Institute, having served on the following AIEE Committees: Communications (1934–37); Standards (1934–39, 1941–43); Basic Sciences (1937–46); Lamme Medal (1940–43); Research (1940–45, 1947–51, Chairman 1949–51); Award of Institute Prizes (1949–51); Technical Program (1949–50).

E. A. Walker (A '34, F '47), director of the Ordnance Research Laboratory and professor and Head of the Department of Electrical Engineering, Pennsylvania State College, State College, Pa., has been appointed Dean of the School of Engineering at Pennsylvania State College. Doctor Walker was born in Long Eaton, England, on April 29, 1910, and received his bachelor, master, and doctor of science degrees at Harvard University. From 1934 to 1940 he taught mathematics and electrical engineering at Tufts College, at the same time conducting research for the Doble Engineering Company, Medford Hillside, Mass. In 1940 he joined the faculty of the University of Connecticut where he remained until 1942. From 1942 to 1945 Doctor Walker served as research director of the Harvard Underwater Sound Laboratory, Cambridge, Mass., where he was in charge of the development of ordnance weapons. In 1945 the Ordnance Research Laboratory was established at Pennsylvania State College

E. A. Walker

with Doctor Walker as its director, and a the same time he held the position of pro fessor and Head of the Department Electrical Engineering. He is also a mem ber of the American Physical Society, th Acoustical Society of America and Ta Beta Pi. He has actively served the In stitute on the following committees: Mem bership (1942–43); Education (1945–51) and Research (1947–51).

A. J. Allen (M '18, F '50), meter enginee Electrical Engineering Department, Co solidated Edison Company of N. Y., Inc New York, N. Y., has retired. He w born on April 2, 1886, in Brooklyn, N. In 1902 he joined the Brooklyn Ediso Company and at night he studied t

ctric light and power business through ernational Correspondence Schools. om 1907 to 1920 he was associated with New York Public Service Commission, coming chief inspector of electric meters. laid out the Public Service Commission oratories, made acceptance tests for ctric transit equipment, and handled tomer meter complaints against utility mpanies. In 1921 he joined the United ctric Light and Power Company as erintendent of meters and tests and, r the formation of the Consolidated ison Company of N. Y., Inc., in 1936 as a ult of merging, Mr. Allen became meter gineer. He has contributed also to the velopment of steam meters, holds many ents, and has written many articles for hnical publications.

L. Olesen (M '27), general sales manager, ston Electrical Instrument Corporation, wark, N. J., is retiring after 20 years' vice to the company. Mr. Olesen was n on November 14, 1895, in Highland k, Ill., and was graduated from the iversity of Illinois in 1918 with a degree electrical engineering. Prior to joining ston he served as a lieutenant in the nal corps during World War I; was a earch engineer with the American Mari Company (now the Radio Corporation America); was an electrical engineer h Fanstell Products Company and with vell Electrical Instrument Company. Olesen is also a member of the Institute Radio Engineers, National Electrical nufacturers Association, and the Radio evision Manufacturers Association.

V. Caton (M '23), chief engineer and nager of electric utility, Winnipeg Electric mpany, Winnipeg, Manitoba, Canada, been elected to honorary membership by Engineering Institute of Canada. norary membership is the highest honor ferred by the Institute which has a total 15,000 members and only 23 honorary mbers. Mr. Caton has been with the nnipeg Electric Company since 1922. was appointed chief engineer in 1936 manager of electric utility in 1948.

N. Walker (A '27, M '34), director of tion research, The BG Corporation, v York, N. Y., has been appointed Vice-sident in charge of Sales for the Richard-Allen Corporation, New York, N. Y. or to World War II Doctor Walker had n professor and Chairman of the Detment of Electrical Engineering at New k University. He has served the Inute on the Education Committee (1937– and on the Instruments and Measurets Committee (1937–42).

H. Chase (M '42, F '51), assistant Vice-ident, Ohio Bell Telephone Company, veland, Ohio, has been appointed deputy ctor of the National Production Aurity's Communications Equipment Divi- in Washington, D. C. Mr. Chase has granted a leave of absence from his pany in order to accept the government assignment. He will be responsible for organizing the division and for its work of allocating strategic materials to manufacturers of communications equipment. Mr. Chase is also a member of Institute of Radio Engineers, the National Society of Professional Engineers, and the American Institute of Physics.

M. A. DeFerranti (M '43), assistant to the manager, aircraft gas turbine divisions, General Electric Company, Lynn, Mass., has been appointed manager of facilities for the General Electric turbojet engine plant, Lockland, Ohio. He was with the International General Electric Company from 1929–35 when he joined the industrial control engineering division. After an absence of six years Mr. DeFerranti became manager of the materials handling division, a position he held until he was transferred to the plant in Lynn. He is currently serving the AIEE on the General Industry Applications Committee.

A. F. Wilson (A '23, M '32), assistant Vice-President, Ohio Bell Telephone Company, Cleveland, Ohio, and **L. C. Balch** (A '22, F '43), chief engineer, Michigan Bell Telephone Company, Detroit, Mich., have been sent to Turkey under the sponsorship of the Economic Co-operation Administration to help plan the reorganization of that country's telephone system.

G. H. Phelps (M '45), commercial engineering, RCA Victor Division, Radio Corporation of America, Camden, N. J., has joined the Hammarlund Manufacturing Company, Inc., New York, N. Y., as chief engineer. His duties will include the administration of the Engineering Department and supervision of the design and development of communications and remote control equipment. Mr. Phelps is also a senior member of the Institute of Radio Engineers.

R. I. Wilson (A '27, M '35), sales engineer, Phelps Dodge Copper Products Corporation, Philadelphia, Pa., has been ordered to a 2-week training period for Naval Reserve Officers at the Naval War College, Newport, R. I. Mr. Wilson holds the rank of Commander in the United States Naval Reserve.

W. A. Weiss (A '42), division manager of quality control, Sylvania Electric Products, Inc., Emporium, Pa., has been appointed manager of the company's new radio receiving tube plant in Burlington, Iowa. Mr. Weiss joined the company in 1940 as a student engineer. In 1942 he was named supervisor of quality control and served in this capacity until 1947 when he became quality control manager for the entire division.

D. O. Eschbach (A '45, M '49), assistant sales manager, switchgear division, Roller-Smith and Elpeco Division, Realty and Industrial Corporation, Bethlehem, Pa., has been appointed general sales manager. Mr. Eschbach's previous experience includes association with Gilbert Associates, Inc., as a consulting engineer, and before that he was employed as an engineer by the switchgear division of the General Electric Company.

Chester Lichtenberg (A '05, F '49, Member for Life), retired, Fort Wayne, Ind., has been elected Vice-President, National Society of Professional Engineers, Central Area. He is also serving as Chairman, Young Engineers Committee, of the Society. Colonel Lichtenberg was retired two years ago by the General Electric Company after 42 years of service.

W. T. Johns, Jr. (A '44), regional manager, Rumsey Electric Company, Richmond, Va., has been elected Vice-President of the company. Mr. Johns was graduated from Virginia Polytechnic Institute in 1925 with a degree in electrical engineering. After employment with the Virginia Electric and Power Company, Richmond, Va., in the Engineering Department, he joined the Rumsey Electric Company in 1929.

A. C. Northover (A '49), resident engineer, McKim Township, Sudbury, Ontario, Canada, has been appointed manager of the Leamington Public Utilities Commission, Leamington, Ontario. The Commission operates the municipal hydro, water, and gas services for the city.

F. H. Roby (A '37, M '41), general sales manager, Square D Company, Detroit, Mich., has been elected Vice-President in charge of sales. Mr. Roby joined the company in 1933 and has served as field engineer, headquarters application engineer, manager of industrial control sales, and general sales manager.

O. P. Proudfoot (M '44), Sales Department, Cutler-Hammer, Inc., Buffalo, N. Y., has been appointed manager of the Cleveland, Ohio, district sales office. Mr. Proudfoot joined the company in 1928 and has served in the sales offices of Pittsburgh, Pa., and Buffalo, N. Y.

J. N. Evans (A '38, M '46), meter superintendent, Manila Electric Company, Manila, Philippines, has been appointed to the staff of the Gaseous Diffusion Plant, operated by the Carbide and Carbon Chemicals Division, Union Carbide and Carbon Corporation, Oak Ridge, Tenn.

OBITUARY • • • •

Ralph Ehrenfeld (M '24), project engineer, Research and Engineering Department, Apex Electrical Manufacturing Company, Sandusky, Ohio, died on January 23, 1951. He was born on September 24, 1887, in Leechburg, Pa., and was graduated from Carnegie Institute of Technology in 1910 with a degree in electrical engineering. The same year Mr. Ehrenfeld became associated with the Westinghouse Electrical and Manufacturing Company (now the Westinghouse Electric Corporation) where he was assigned to the Small Motor Department and served as its manager for a number of years. In 1939 he joined the Apex Electrical

Manufacturing Company where he was in charge of small motor engineering. Mr. Ehrenfeld served the AIEE on the Electrical Machinery Committee from 1933–34.

Herman Theodore Kohlhaas (A '07, M '19, F '48, Member for Life), retired, New York, N. Y., died on April 24, 1951. He was born on December 28, 1882, in Brooklyn, N. Y., and was graduated from Cooper Union in 1907. Mr. Kohlhaas, retired assistant Vice-President of International Telephone and Telegraph Corporation (I.T.&T.), joined the Western Electric Company Laboratories (now Bell Laboratories) in 1905 and from then until 1922 he served as engineer, section head, and finally as a division head in the physical laboratory. In 1925 he was appointed editor of *Electrical Communication*, and in 1945 he was made assistant Vice-President of I.T.&T. and served in that capacity until his retirement in 1947. He was also a senior member of the Institute of Radio Engineers.

William D. Howze (A '36), owner, W. D. Howze and Company, Los Angeles, Calif., died on April 16, 1951. He was born in Denver, Colo., on August 21, 1896. From 1927–31 he was the Pacific Coast representative for the Everstick Anchor Company. Mr. Howze was also associated with the Bowie Switch Company, San Francisco, Calif.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners at its meeting of May 17, 1951, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Fellow

Almquist, M. L., transmission engr., Bell Telephone Laboratories, New York, N. Y.
Appleman, W. R., development engr., Master Electric Co., Dayton, Ohio
Baker, E. W., plant extension engr., American Tel. & Tel. Co., New York, N. Y.
Bode, H. W., research mathematician, Bell Telephone Laboratories, Murray Hill, N. J.
Dodge, C. C., electrical engr., Stone & Webster Engineering Corp., Boston, Mass.
Foulon, F., electrical group engr., Douglas Aircraft Co., El Segundo, Calif.
Fountain, L. L., mgr. technical section, Westinghouse Electric Corp., East Pittsburgh, Pa.
Geiges, K. S., assoc. electrical engr., Underwriters' Laboratories, Inc., New York, N. Y.
Hardaway, W. D., supt. hydroelectric production & transmission, Public Service Co. of Colorado, Denver, Colo.
Holmes, L. C., director of research, Stromberg-Carlson Co., Rochester, N. Y.
Nason, H. E., industrial engg. supervisor, Westinghouse Electric Corp., Chicago, Ill.
O'Brien, J. E., chief, technical standards div., Rural Electrification Administration, Washington, D. C.
Pakala, W. E., liaison engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
Persons, J. T., vice pres. & chief engr., Central Power & Light Co., Corpus Christi, Tex.
Putnam, R. C., professor of elec. engg., Case Institute of Technology, Cleveland, Ohio
Ramo, S., co-director, research & development labs., Hughes Aircraft Co., Culver City, Calif.
Roberts, E. A., director, The Roberts Organization, New York, N. Y.
Webb, R. L., asst. division engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Werly, B. M., supt., shops & field depts. Eastman Kodak Co., Rochester, N. Y.
Witzke, R. L., central station engr., Westinghouse Electric Corp., East Pittsburgh, Pa.

20 to grade of Fellow

To Grade of Member

Andersson, M. A., engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Antofilli, V., elec. engineer, Ebasco Services, Inc., New York, N. Y.
Barnes, T. F., asst. chief inspector, The Detroit Edison Co., Detroit, Mich.
Boyer, J. L., mgr., rectifier development section, Westinghouse Electric Corp., East Pittsburgh, Pa.
Brannen, P. M., patent engr., Union Switch & Signal Co., Swissvale, Pa.
Burgess, M. L., manager, Westinghouse Electric Corp., Omaha, Nebr.
Cambias, S., Jr., asst. electrical engineer, New Orleans Public Service Inc., New Orleans, La.
Carpenter, E. K., electrical engineer, U. S. Bureau of Reclamation, Boulder City, Nev.
Carson, R. N., district engr., Southwestern Bell Tel. Co., Houston, Tex.
Cheney, F. C., electrical engineer, Stone & Webster Engineering Corp., Boston, Mass.
Chernish, G., asst. to chief electrical engineer, Canadian Comstock Co., St. Catharines, Ontario, Canada
Corcoran, E. G., electrical designer, Douglas Aircraft Co., Inc., El Segundo, Calif.
Correy, T. B., electrical engineer, General Electric Co., Richland, Wash.
Crookston, J. G. W., electrical engineer, Canadian Brazilian Services, Ltd., Toronto, Ontario, Canada
Curtis, C. H., electrical engineer, United Engineers & Constructors, Inc., Philadelphia, Pa.
Fay, R. D., associate professor, Massachusetts Institute of Technology, Cambridge, Mass.
Faver, W., elec. design engineer, dept. of water & power, City of Los Angeles, Calif.
Felix, H. E., model leadman, Douglas Aircraft Co., Santa Monica, Calif.
Fogg, J. N., power supt., Ethyl Corp., Baton Rouge, La.
Fowler, N. B., div. plant supervisor, American Tel. & Tel. Co., Atlanta, Ga.
Frazier, J. F., development engineer, Corning Glass Works, Corning, N. Y.
Fuller, L., manager, switchgear application, Westinghouse Electric Corp., East Pittsburgh, Pa.
Gara, W. B., plant engineer, Standard Brands, Inc., Washington, D. C.
Hatch, J. A., asst. engineer, Pacific Gas & Electric Co., San Francisco, Calif.
Hobbs, W. E., plant extensions engineer, The Chesapeake & Potomac Tel. Co. of Virginia, Richmond, Va.
Horelick, A. L., engineering manager, Pennsylvania Transformer Co., Canonsburg, Pa.
Hudson, M. B., electrical maintenance supervisor, Shell Oil Co., Zionsville, Ind.
Huse, R. A., asst. engineer, Public Service Electric & Gas Co., Newark, N. J.
Jensen, O., manager, rectifier div., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Jones, A. R., assoc. engineer, Long Island Lighting Co., Garden City, N. Y.
Keistman, A. R., manager, engineering section, Jack & Heintz Precision Industries, Inc., Cleveland, Ohio
Kimball, R. B., engineering div., General Electric Co., Los Angeles, Calif.
Kirschbaum, H. S., asst. professor of electrical engg., Ohio State University, Columbus, Ohio
Kozak, T. J., methods engineer, The Toledo Edison Co., Toledo, Ohio
Lautz, P. O., asst. engineer, The Atchison, Topeka & Santa Fe Railway Co., Topeka, Kans.
Lawyer, H., engineer, Oklahoma Gas & Electric Co., Oklahoma City, Okla.
Leach, H. W., electrical engg. & physics professor, Tarleton State College, Stephenville, Tex.
Luckey, R. W., general engineer, Atomic Energy Commission, Richland, Wash.
Lyon, G., engineer-in-charge, network analysis dept., Associated Electrical Industries, London, England
Macpherson, H. W., asst. engineer, The T. Eaton Co., Ltd., Hamilton, Ontario, Canada
Mallinckrodt, C. O., member of technical staff, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
Marcum, C. R., manager, rectifier engg. section, Westinghouse Electric Corp., East Pittsburgh, Pa.
Marmaros, H. E., engineer, N. A. Lougee & Co., Inc., New York, N. Y.
Marquardt, H. W., regional director, Westinghouse Electric International Co., New York, N. Y.
Mars, H. L., pile engineer, General Electric Co., Richland, Wash.
McDougal, I. E., application engineer, Westinghouse Electric Corp., San Diego, Calif.
Metz, J., supervising engineer, Commonwealth Edison Co., Chicago, Ill.
Nemetz, V., asst. professor of electrical engg., University of Wisconsin, Madison, Wis.
Nicholson, G. J. G., Jr., electrical engineer, Newport Electric Corp., Newport, R. I.
Pogorzelski, R. J., owner, Pogo Electric Co., Van Dyke, Mich.
Ratliff, K., manager, Allis-Chalmers Mfgr. Co., Fort Worth, Tex.
Rennie, W. A., design elec. engr., National Tube Co., Lorain, Ohio
Scussel, F. G., asst. chief, resources & development div., U. S. Bureau of Reclamation, Boulder City, Nev.
Sievers, G. A., president, Industrial Engineering Institute, Milwaukee, Wis.
Smith, G. A., Jr., president & engineer, Central Station Alarm Co., Dallas, Tex.
Snyder, F. D., consulting & application engg. supervisor, Westinghouse Electric Corp., Boston, Mass.
Spicer, G. W., engineer, I-T-E Circuit Breaker Co., Philadelphia, Pa.
Spracher, P. R., engineer, Virginia Electric & Power Co., Richmond, Va.
Steinbrook, S. E., senior design engineer, Baldwin-Lima, Hamilton Corp., Philadelphia, Pa.
Storry, J. O., assistant professor of electrical engg., South Dakota State College, Brookings, S. D.
Stottler, M. W., engineer, Westinghouse Electric Corp., Philadelphia, Pa.
Sturdy, W. W., chief, communications div., Sixth Army, Presidio of San Francisco, Calif.
Taylor, F. C., asst. engineer, Fall River Electric Light Co., Fall River, Mass.
Thompson, R. J., partner, Carnahan & Thompson, Engineers, Oklahoma City, Okla.
Tsui, J. H., design engineer, Westinghouse Electric Corp., Sharon, Pa.
Turner, J. C., construction supervisor, Southwestern Bell Telephone Co., Oklahoma City, Okla.
Turner, R. H., electrical engineer, United Engineers & Constructors, Inc., Philadelphia, Pa.
Warnock, E. W., associate engineer, Consumers Power Co., Jackson, Mich.
Westmann, C. L., supt., southern hydro div., Southern California Edison Co., San Bernardino, Calif.
Zastrow, O. W., engineer, Rural Electrification Administration, Washington, D. C.

70 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before July 25, 1951, or September 25, 1951, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Ashley, J. R., Magnolia Pipe Line Co., Dallas, Tex.
Barlow, S. L. M., Barlow & Young, Ltd., London, England
Bergey, J. S., Raymond Rosen Engg. Products Co., Inc., Philadelphia, Pa.
Blythe, E. G., Northwestern Bell Telephone Co., Omaha, Nebr.
Brewer, G. E., Westinghouse Elec. Corp., Sharon, Pa.
Cheever, A. H., Lockwood Greene Engineers, Inc., Boston, Mass.
Cox, A. G., Robert E. Foley Construction Corp., Binghamton, N. Y.
DuBois, M. A., DuBois Engg. & Mfg. Co., Hammond, Ind.
Dunlap, W. C., Jr., General Elec. Research Lab., Schenectady, N. Y.
Frei, C. G., General Elec. Co., New York, N. Y.
Gilmore, J. L., Mathieson Chemical Corp., Lake Charles, La.
Gorman, E. B., Pacific Elec. Mfg. Corp., San Francisco, Calif.
Henning, E. S., Navy Dept., Bureau of Ships, Washington, D. C.
Hoyler, C. N., RCA Laboratories, Princeton, N. J.
Jackson, R. C., U. S. Govt., Dept. of Interior, Albuquerque, N. Mex.
Johnson, W. E., Navy Dept., Taylor Model Basin, Washington, D. C.
Kirkham, E. H., Phelps Dodge Copper Products Corp., Yonkers, N. Y.
Klekotka, O. S. A., Rev. J. A., Villanova College, Villanova, Pa.
Lamberton, C. J., General Elec. Co., Pittsfield, Mass.
Lin, C. Y., The Ministry of Industry in Eastern China, Shanghai, China
Locke, P. B., Florida Power Corp., St. Petersburg, Fla.
McCamish, W. R., Darby Corp., Kansas City, Kans.
Moore, G. M., Jr., Palmer & Baker, Mobile, Ala.
Moran, R. B., Jr., Moran Instrument Corp., Pasadena, Calif.
Nickell, D. H., Square D Co., Cleveland, Ohio
Olsen, W. C., Building & Loan Bldg., Raleigh, N. C.
Owens, W. B., Ohio Brass Co., Atlanta, Ga.
Parsons, E. A., Senior High School, Great Falls, Mont.
Potts, H. C., Vanderbilt University, Nashville, Tenn.
Ramrath, J. M., Allis-Chalmers Mfg. Co., Boston, Mass.
Ruhlen, L. H., Commonwealth Associates Inc., Jackson, Mich.
Saums, H. L., Anaconda Wire & Cable Co., Muskegon, Mich.
Shepherd, W. G., University of Minnesota, Minneapolis, Minn.
Swaminathan, R. K., Govt. Electricity Dept., Wardha, C. P., India
Valentine, W. W., Potomac Elec. Power Co., Washington, D. C.
Vossberg, C. A., The Electron-Machine Co., Lynbrook, N. Y.
Waghorne, J. H., Hydro-Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Widgery, K. H., 88 Wanstead Park Ave., London, England
Youd, J. R., Gulf Power Co., Panama City, Fla.

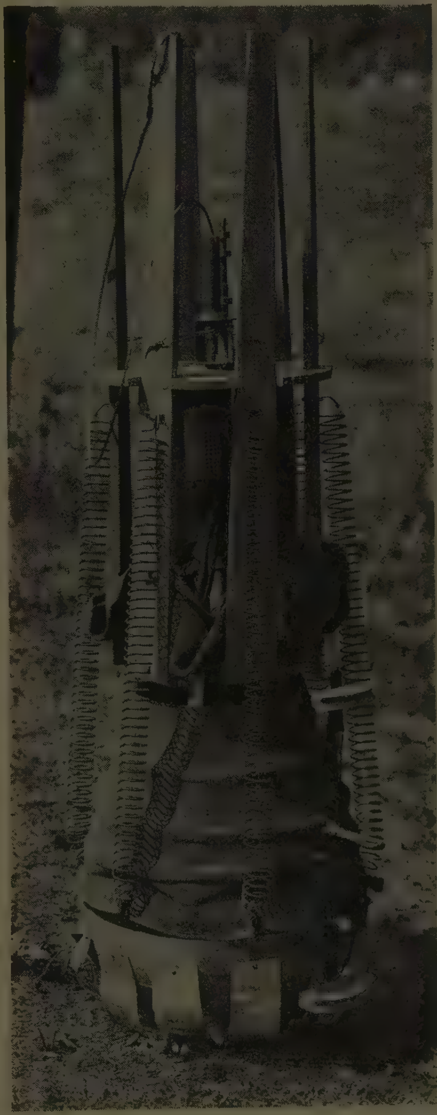
39 to grade of Member

ir-Launched Automatic Weather Station Transmits Data by Radio

A self-contained automatic weather sta-n, which transmits weather data by radio a frequency of five megacycles at 3-hour ervals for about 15 days, has been de-oped by the National Bureau of Standards BS) for the Navy Bureau of Ships. Named Grasshopper, the device can be para-uted from aircraft onto inaccessible terri-y. Developed during World War II, it tomatically will set itself up and periodi-lly make and transmit weather observa-ns over a range of 100 miles. It also may used as a radio marker beacon.

Designed in the shape of a bomb, and cking its own parachute, the weather sta-n is loaded on the bomb rack of an air-aft. When the unit is released over a de-ed location, the parachute is opened auto-atically by a line rigged from the aircraft. multaneously, an electric clock, which con-ols subsequent operations of the station, is rned on. The impact of landing sets off a all explosive charge which disengages the rachute and prevents the station from be-g pulled along the ground. Either imme-ately or after a preset dormancy period, other explosive charge causes the station to e to an upright operating position. This done through an arrangement of six legs which springs are attached; the explosive arge operates a release, permitting the rings to pull the legs into position. A ird explosive charge extends a telescopic rtical antenna to a height of some 20 feet. he station is then ready for automatic nsmission at intervals predetermined by e built-in timing mechanism.

Separate mechanisms responsive to anges in atmospheric conditions each use an associated resistor to vary. At pre-termined intervals the timing mechanism rns on the radio transmitter with a 5-watt tput and connects one resistor after another to a critical point in the transmitter circuit. The transmitter is designed so that the emitted radio signal pulses on and off at a rate proportional to the value of the resistor so connected. The station is calibrated be-fore use by subjecting it to known tempera-tures, pressures, and humidities and measur-ing the resulting pulse rates. At the receiv-ing station the transmitter pulse rate then can be read as temperature, pressure, or humidity, depending on the phase of the predetermined clockwork cycle.



Model of the air-launched automatic weather station developed by the NBS. The station has landed and the impact will set off an explosive charge which will disengage the parachute. Another charge will operate a leg-release de-vice which will permit the springs to pull the legs into an upright position

The battery-powered radio transmitter proper consists of a crystal oscillator followed by a radio-frequency amplifier stage. A re-lay in the plate circuit of a separate relax-ation oscillator turns the crystal oscillator on and off at a rate proportional to the value of whatever resistor is inserted temporarily (by the clock mechanism) into the relaxation oscillator circuit. When the station is to be used as a beacon, the radio transmitter and its control mechanisms may be simplified.

The clock, in addition to inserting the several weather-responsive resistors into the circuit in a predetermined sequence, con-nects two other constant-value resistors at appropriate intervals; these are a reference resistor and an identification resistor. The pulse rate produced by the fixed reference resistor is observed during initial tests of the transmitter. Any subsequent deviation in the reference resistor pulse rate warns the re-ceiving station that a correction factor must be applied to the pulse rates of the weather-responsive resistors. Such deviation could arise from transmitter damage or aging. The identification resistor is selected to pro-duce a pulse rate characteristic of the partic-ular station; this enables the receiving sta-tion operator to identify the station.

A special technique is used to insure maxi-

The Grasshopper is ready to transmit weather data by radio. The telescop-ing antenna, disengaged by an explosive charge, is raised to a height of 20 feet

uture Meetings of Other Societies

erican Electroplaters' Society. July 30–August 2, 51, Statler Hotel, Buffalo, N. Y.

draulic Institute. September 5–7, 1951, The Drake tel, Chicago, Ill.

minating Engineering Society. National Tech-al Conference. August 27–30, 1951, Hotel Shore-n, Washington, D. C.

titute of Aeronautical Sciences. Annual Summer eting. June 27–28, 1951, Institute of Aeronautical ences, Western Headquarters Building, 7660 Beverly ulevard, Los Angeles, Calif.

titute of Navigation. Seventh Annual National eting. June 28–30, 1951, New Yorker Hotel, New k, N. Y.

titute of Radio Engineers. Western Convention l Seventh Annual Pacific Electronic Exhibit. August -24, 1951, Civic Auditorium, San Francisco, Calif.

trument Society of America. Sixth National In-ment Conference and Exhibit. September 10–14, 51, Sam Houston Coliseum, Houston, Tex.

mum accuracy of the transmitted data despite possible deformation of the weather-responsive mechanisms due to landing impact: a buzzer vibrates each weather-responsive device for a short time before its associated resistor is inserted in the relaxation oscillator circuit. This forced vibration counteracts friction, increased by landing-impact deformation, and thus aids in the attainment of a true equilibrium condition.

Flexible Test Room Facilitates Investigation of Lighting Systems

Design of modern lighting systems for factories, offices, stores, schools, homes, and other indoor areas will be facilitated through the work of a new lighting measurements laboratory at Nela Park, Cleveland, Ohio, headquarters of General Electric's Lamp Department.

This laboratory is producing pretested data which will make it possible to predetermine the illumination resulting from any type of lighting system in all sizes and proportions of rooms, taking into account a complete range of room finishes.

Some of the first studies to be made will contribute information needed for lighting in the nation's production program. Good industrial lighting is closely allied to high production, quality, safety, and morale.

By means of a flexible test room, a mechanized light cell, and instruments which automatically record and translate the cell's measurement of light into information required by illuminating engineers, it now is possible to obtain in hours lighting data which formerly took days of tedious effort to accumulate.

At one time most lighting was done with simple filament units regularly spaced in a room. Now, however, lighting systems are varied considerably more in character, in the size and shape of units, and in their placement and lighting characteristics. The new laboratory will provide pretested information with which lighting engineers will be better able to solve today's more complex illumination problems.

The new laboratory's studies are made in what is believed to be one of the most flexible rooms ever built. Dimensions can be varied from 12 to 30 feet square, and the ceiling can be raised as high as 16 feet. Ceiling, wall, and floor panels can be changed quickly to any desired pattern of color or reflectance, and lighting fixtures and lamps of any type can be installed and shifted about in any position desired.

The novel use of instruments greatly accelerates measurements. Illumination in any plane is quickly explored by a light cell which is moved automatically across the room on a small, mechanized carriage operating on a track. The cell is connected to recording instruments outside the test room. These automatic instruments are synchronized with the movement of the cell. They record levels of illumination and simultaneously translate the results into design data required by lighting specialists.

A flexible room, a mechanized light cell, and instruments which automatically record and interpret the amount of light being measured are shown here as part of General Electric's new lighting measurements laboratory. The light cell in the test room whose ceiling has been lowered to demonstrate its flexibility is being adjusted

Part of Brookhaven Reactor Declassified for Research

The United States Atomic Energy Commission (AEC) has approved declassification of the west face of the recently completed nuclear reactor at Brookhaven National Laboratory, Upton, N. Y. The Commission action was taken in order that maximum possible use can be made of the Brookhaven reactor's research capacities.

The Brookhaven reactor began operation on August 22, 1950. It is the nation's largest research reactor and is the only one in northeastern United States. Its primary purpose is to produce neutrons for scientific research. It was designed especially to accommodate a larger number of simultaneous experiments than is possible with any other known reactor.

Steel partitions 30 feet high have been erected to separate and screen the declassified reactor face from the remaining classified areas around the pile and traffic from one section to the other will be allowed only through a closely guarded door. An unclassified portion of the adjacent pile laboratory, where special facilities and equipment make possible the study of dangerously radioactive samples, also will be made available to the researchers.

Scientists wishing to use these newly declassified facilities will not need the AEC security clearance (based on an investigation by the Federal Bureau of Investigation of the character, associations, and loyalty of the individual) which is required of those working on classified research or in classified areas of the laboratory. The use of the declassified reactor facilities will, however, be subject to the approval of the laboratory director and the AEC. Those requesting such use will be required to complete and sign a Personnel Security Questionnaire, including a listing of all affiliations, which will be reviewed by the Commission's New York Operations Office. In addition, the declassified area will at all times be under the surveillance of fully cleared personnel who are aware of security requirements regarding the reactor.

Despite the fact that since the war much nonclassified research has been done at universities and private laboratories, the extent to which some studies could be pursued has been limited by the equipment available. The declassification of one phase of the Brookhaven Reactor will make research with neutrons possible on projects initiated outside the AEC program which, nevertheless, relate to Brookhaven's over-all research program.

New Issue of Guidance Manual Published by ECPD

A guidance manual intended for engineers aiding young men who are interested in the engineering profession was published recently by the Engineers' Council for Professional Development (ECPD), New York, N. Y. The 15-page pamphlet, prepared by the ECPD Guidance Committee, urges members of local engineering societies and sections and chapters of national engineering societies to establish guidance committees to aid high-school pupils to determine whether they are qualified for careers in engineering. The present critical engineering manpower

hortage emphasizes the need for guidance f the type indicated in this manual.

The manual explains briefly how to rganize advisory committees and how to elect committee members. The manual ontains suggestions for working with high chool and secondary school students and sts aids especially useful in counseling high-chool boys. The guidance manual is sup-lemented by an appendix, "Shall I Study ngineering?" which is a questionnaire to be lled out by the student for use of the engi-eer who is advising him.

Copies of the manual with questionnaire nay be obtained from ECPD, 29 West 39th treet, New York 18, N. Y. Price of com-ination, 20 cents; cost of the manual if urchased separately is 15 cents. The price f the questionnaire is ten cents. A deduc-ion of 25 per cent for purchases of 25 or more s allowed.

The ECPD is a conference of engineering odies organized to advance the engineer rofessionally through the co-operative sup-ort of its national organizations directly epresenting the professional, scientific, edu-ational, and legislative phases of the engi-eer's life.

Tilting of Antenna Increases UHF TV Station Signal Strength

Television signals in the program service rea of an ultrahigh-frequency (UHF) sta-ion can be doubled in strength by a slight ilting of the transmitting antenna. In de-ermining the effect of tilting the antenna rom its normally vertical position, the Radio Corporation of America (RCA) used the acilities of RCA-National Broadcasting Company's experimental station *KC2XAK* which has been in operation near Bridgeport, Conn., since 1949.

The antenna built for the tests was erected n one side of the Bridgeport transmitting ower. By means of a motor-driven arrange-ment, the antenna was rocked back and forth n an arc of approximately 12 degrees to per-mit engineers to record the resulting vari-tions in signal strength. Field tests were nade at several locations in the primary ervice area of *KC2XAK* and also at Prince-on, N. J., 90 miles away. Results showed that he received signal was at its maximum when he antenna was tilted 2.5 degrees up or down.

This gain in signal strength, achieved without increasing the power of the trans-mitter, would be particularly valuable in the resent state of development of the UHF art. Unlike the very-high-frequency (VHF) sta-ons now providing program service to the ublic, UHF stations are limited in their ower by the types of electron tubes available or transmitters. By making use of the addi-onal signal strength which the tilted an-enna delivers, the effect on the quality of the elevision picture would correspond to that which would be produced if the power of the ransmitter were to be multiplied several mes. Furthermore, this gain would bring bout a noticeable improvement in picture uality on UHF television receivers installed n the outer areas of program service.

Because of the occasional propagation of aves well beyond the normal coverage of a ation, further tests will be conducted to etermine whether the gain in signal strength roduced by the tilted antenna is likely to increase interference with distant stations operating on the same or adjacent channels.

The transmitting tower of RCA-NBC's experimental ultrahigh-frequency TV station near Bridgeport, Conn., is shown. The antenna, on the left side, when tilted, increases the signal strength to that which would be obtained by doubling the power of the transmitter

Plans are being considered to conduct re-search on tilted antennas in the VHF field. If corresponding gains are obtained on these channels now used by commercial television stations, their program service areas would be extended similarly. The pictures then ob-tainable at points 35 to 50 miles for trans-mitters would compare more favorably in quality with those now being enjoyed at locations much closer to the stations.

Super Vacuum Bottle Holds World's Coldest Liquid 100 Days

A vacuum bottle that can hold the world's coldest liquid 15 times longer than the best container previously available has been de-veloped at the Westinghouse Research Laboratories, Pittsburgh, Pa. A copper vacuum bottle has been perfected that will hold four gallons of liquid helium, used by scientists in studies of materials at subzero temperatures, at a temperature of only eight degrees above absolute zero (−459.8 degrees Fahrenheit) for 100 days.

The new vacuum bottle consists of two highly polished copper spheres, one inside the other, about a foot in diameter. Most of the air is evacuated from the area between the two spheres. The bottle is immersed in a tank of liquid nitrogen at a temperature of −300 degrees Fahrenheit to minimize heat losses.

Heart of the new device is contained in the long narrow neck tube through which the liquid helium is poured. Since practically all of the heat transmitted into the interior of the bottle is conducted down the surface of the neck tube, the neck is designed to cut these losses to a minimum. This was done by making the tube slightly more than a half-inch in diameter, increasing its length, and using thin-walled metal. Through such de-sign, it was possible to reduce the heat in-flow by 90 per cent.

The super-cold helium vapors coming from the container serve to refrigerate the neck tube. This essentially neutralizes the transmitted outside heat and thereby nar-rows the temperature gap between the tube and the helium. By improvements in the design of the tube it is predicted that even more efficient containers could be developed.

When liquid helium evaporates, it builds up pressures in the container. If a "cork" were put on the bottle, the pressures would go high enough to cause an explosion. So a tiny opening at the top of the container is provided to act as a safety valve. The new vacuum bottle answers the need for a long-time storage container for liquid helium, and may help bring about a radical change in present shipping methods for such refriger-ants. Because liquid helium evaporates very rapidly—840 times faster than water does at the boiling point—it has been neces-sary to ship it as a gas and then liquify it at the point of use. This has required the use of heavy steel containers and very high pres-

A Westinghouse scientist is shown lifting a super vacuum bottle from its container of nitrogen. The copper bottle holds four gallons of liquid helium at a temperature of eight degrees above absolute zero

sures to keep the volume of the gas down to a minimum. With the new vacuum bottle it may be possible to ship liquid helium in thin-walled containers at ordinary atmospheric pressure, thus effecting a savings in both space and materials.

Experts Sent by ECA to Turkey to Reorganize Phone System

Seven Bell Telephone experts have been sent to Turkey, under the sponsorship of the Economic Co-operation Administration (ECA) and the Turkish government, to plan the reorganization of that country's telephone system during a 1-year stay in a project that is deemed highly important for both strategic reasons and for the requirements of Turkey's economy. Turkey at present has no telephone communications, either by land line or radio, with any other country.

The work of the group, headed by Earl D. Wise, retired Vice-President and general manager of the Pacific Telephone and Telegraph Company, is being financed by an ECA appropriation of $79,000 and approximately $60,000 authorized by the Turkish government. The ECA is paying the salaries of the seven men, plus assuming the expenses incurred by Mr. Wise in travelling around the United States to conduct interviews preparatory to organizing the team of experts, while the Turkish grant will pay for the travel expenses to and from Turkey for members of the group as well as living and travelling expenses while in Turkey.

In addition to Mr. Wise, other members of the team, with a collective experience of more than 260 years of telephone company operation, are: W. E. Badden, construction superintendent of the Michigan Bell Telephone Company; L. J. Simonich, outside plant engineer, Illinois Bell Telephone Company; J. E. Mannocci, assistant Vice-President in charge of personnel for Pacific Telephone and Telegraph Company; A. F. Wilson, retired assistant Vice-President in charge of commercial operations for the Ohio Bell Telephone Company; V. E. Tyson, retired division plant personnel supervisor, New England Telephone and Telegraph Company; and E. C. Balch, chief engineer of Michigan Bell Telephone Company.

The specific job of the seven United States specialists will be in four parts: they will make a complete survey of existing telephone installations and what can be done with present plants; survey what future requirements will be; develop a fundamental plan of extension of plant so additions will be co-ordinated into the whole system; and make recommendations for the necessary reorganization and additions. During the first two months of their task, they also will work with 10 Turkish technical school graduates who are to come to this country.

Naval Laboratories Need Technical Personnel

The United States Naval Air Development Center, Johnsville, Pa., is accepting applications for engineering and other technical positions from high-grade engineering, scientific, and mechanical personnel with education, training, or experience in the fields of aeronautical, mechanical, electrical, and electronics engineering, or in the fields of physics, mathematics, biology, and clinical psychology. It is also looking for engineering draftsmen and laboratory mechanics who have considerable experience in aeronautical, electrical, electronics, or mechanical drafting of shop work.

The Navy Department feels that it can offer some of the following benefits to technical and scientific personnel: variety of research; opportunities for professional recognition; opportunities for graduate study (through co-operative arrangements with the University of Pennsylvania's Moore School of Electrical Engineering); opportunities for advancement; and many others.

Under the field of electrical engineering are the following suboptional fields: aircraft electrical systems; control; electrical components; test and evaluation; and laboratory and plant facilities.

Positions currently available range in salary from $2,200 to $10,000 per annum. Inquiry regarding the positions described should be made to the Industrial Relations Officer, United States Naval Air Development Center, Johnsville, Pa.

World's Tallest TV Towers Now Under Construction

IDECO, a Division of Dresser Equipment Company, Dallas, Tex., announces acceptance of contracts for the construction of two of the world's tallest television towers. These towers are being built for radio stations *WTMJ* Milwaukee, Wis., and *WBEN* Buffalo, N. Y., and are being furnished through the Radio Corporation of America by IDECO of Columbus, Ohio. The *WTMJ* tower will be 1,017 feet in height and the *WBEN* tower is to be a cloud-piercing 1,057 feet tall which will equal the height of the world's tallest tower developed by IDECO for Radio Station *WCON* in Atlanta, Ga. Both of the new towers will be of triangular construction similar to the Atlanta tower.

Westinghouse to Build Largest Gas Turbine for Electric Power

Sale of the largest gas turbine-generator yet ordered for the commercial generation of electric power was announced recently by the Westinghouse Electric Corporation, South Philadelphia, Pa. The unit, a 15,000-kw machine, will be installed in the Bartlesville area of the Public Service Company of Oklahoma. Natural gas from the Oklahoma fields will provide the heat energy which the new turbine will convert into electric power. It is scheduled for delivery from the Westinghouse Steam Division in about three years.

The 700,000-pound turbogenerator installation will consist of the gas turbine as the primary source of power, driving a hydrogen-cooled generator. The gas turbine will comprise high- and low-pressure turbines driving high- and low-pressure compressors, respectively, with the high-pressure turbine also connected to drive the generator. Intercoolers will reduce the temperature of the compressed air between stages of compression, and a regenerator will apply exhaust-gas heat to the air before it enters the combustor to reduce consumption of fuel.

The turbines will operate at a temperature of 1,350 degrees Fahrenheit—300 degrees higher than even the hottest steam temperatures in use today in electric generating stations, and about twice as high as the temperature of the average steam-generating plant. Speed of the turbine will be 3,600 rpm. At full load the compressors will draw in $7^1/_2$ tons of air every minute.

National Groups Represented at Civil Defense Meeting

President Truman, Secretary of Defense George Marshall, and Governor Earl Warren of California spoke at the Civil Defense Conference of National Organizations on May 7–8, 1951, in Washington, D. C. The keynote of the meeting was the need for arousing public interest in immediate civil defense preparation against enemy attack. The conference was called for the purpose of mobilizing the civil leadership of the nation and was attended by 1,000 leaders of approximately 300 national organizations with a total membership of about 50,000,000. Representing the AIEE were past President James F. Fairman and Arthur H. Kehoe.

Several publications containing vital information on civil defense are available. They are: United States Civil Defense; Health Services and Special Weapons Defense; Survival Under Atomic Attack; This Is Civil Defense; What You Should Know about Biological Warfare; The Alert Card; Fire Effects of Bombing Attacks; Medical Aspects of Atomic Weapons; Damage from Atomic Explosions and Design of Protective Structure. These publications may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Other publications in the process of being published include: The Police Service; The Rescue Service; Vulnerability of Cities; Civil Defense in Industry and Institutions; The Warden Service and The Fire Service.

Everyone is urged to do their part for Civil Defense which for many individuals means staying on the job in their own organization where their efforts are as essential to the public welfare as air-raid wardens or rescue crews.

Meeting Held to Promote Safety on Great Lakes by Means of Radio

Representatives of various governmental and nongovernmental bodies of the United States and Canada, interested in the promotion of safety of life and property on the Great Lakes by means of radio communication, met in conference in Ottawa from May 7–10 for the purpose of negotiating an agreement to revise and co-ordinate existing requirements. The conference recessed after having given careful consideration to all technical details. It will be reconvened at a later date.

The conference agreed on the need for making compulsory the carriage of radio-telephone equipment on ships of 500 gross

tons and over and on passenger-carrying vessels over 65 feet in length. All such ships would be required to maintain a constant listening watch on the distress and calling frequency. This radio-telephone watch would be maintained by either the master, mates, or other members of the crew, each of whom would be certificated for such duties. This would be in addition to their other duties while on the bridge.

The effect of a draft agreement prepared would be to provide for the authorized use of radiotelephony as a means of communication of distressed signals for shipping on the Great Lakes. The distress frequency (2,182 kc per second) and the present working frequencies would continue to be used. Decisions reached by representatives of the two countries would become effective on the Great Lakes and the St. Lawrence river as far east as Montreal.

GE Test Stand Duplicates Aircraft Power Systems

A testing system that can duplicate the complete electric system of an airplane at speeds and loads equivalent to actual flight operation is currently in operation at General Electric Company, Schenectady, N. Y.

Designed for the development as well as testing of new equipment, the system consists of three test stands, each powered by a 450-horsepower radial aircraft type engine. Through step-up gear boxes, and with forced ventilation, generators and alternators function at flight conditions.

Capable of testing normal loads as well as short circuits and overvoltages, the test stands determine whether generators, distribution circuits, and control systems can operate satisfactorily under all generator speeds. The stands also test for overloads, conditions of reduced generation capacity, and any abnormal conditions such as failures or faults.

During tests on short circuits, the normal loads of landing and cabin lights, radio, and landing gear operation are simulated by resistors immersed in a water box. Copper cables run to ground provide faults required to test new protective devices which automatically clear the entire system and only eliminate the defective part.

Currently being used for the development of 28-volt d-c systems for commercial and military aircraft, as well as 400-cycle a-c and 120-volt d-c control systems, the test duplication system has been instrumental in gaining basic knowledge of electrical performance as well as aiding in the design of new equipment. In addition, the test system coordinates the manufacture of aircraft components, enabling engineers to find operating and other discrepancies in new equipment before it is used in actual operation.

Schools Must Double Enrollment to Meet Shortage of Engineers

In order to meet the country's demand for engineers, more than 30,000 of them must be graduated from the engineering schools each year. Since the "mortality" rate in engineering schools is about 50 per cent, an annual freshman enrollment of 60,000—double the number that entered engineering schools this year—would be required to produce 30,000 engineering graduates a year.

Every effort must be made to impress high-school principals, counselors, and students with the critical shortage of engineers in all fields. One of the groups most active in this task is the Engineering Manpower Commission of the Engineers Joint Council. More than 23,400 high-school principals throughout the nation have just received copies of a leaflet setting forth the salient facts of the shortage and strongly urging high-school authorities to direct qualified seniors into engineering schools.

Sawdust Made Available for Cattle Fodder by Cathode Rays

Sawdust may be a practical food for cattle some day, according to General Electric scientists.

Experiments conducted in the General Electric Research Laboratory, in collaboration with the department of bacteriology at the State College of Washington, Pullman, Wash., show that irradiation with high-voltage electrons, or cathode rays, makes part of the sawdust digestible by organisms in the cow's stomach.

According to the scientists, a cow is able to utilize pure cellulose (such as cotton) as food. Wood consists largely of cellulose, combined with another compound, called lignin, in which combination it is indigestible. The cathode rays make the cellulose available. Bacterial action in the rumen, the first of the cow's four stomachs, is able to convert the cellulose into several other compounds, such as acetic, propionic, and butyric acids. These are generally known as the volatile acids, and can be absorbed in the animal's intestines.

Sawdust has been used in Europe for cattle fodder by giving it a sulfuric acid treatment, which breaks down the lignin and makes the cellulose available for digestion in the rumen. It is believed that the cathode-ray treatment may prove simpler and less expensive.

Celebration to Mark Progress of Rural Electrification

The electric light and power industry will observe the week beginning August 26, 1951, as Rural Electrification Week. Special activities have been planned by the utilities to mark the progress that has been made in bringing electric power to the nation's farms since 1923. By the end of this year electricity will be available to 95 per cent of the farms; this achievement will be celebrated nationally by companies, industries, and organizations that have contributed to the expansion of our agricultural economy.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Motion of an Iron Rod

To the Editor:

In his Electrical Essay (*EE, Mar '51, pp 254–6*), Dr. J. Slepian, in his most interesting discussion of the induced electromotive force in the familiar text-book "sliding-bar" circuit when the moving bar is made of iron, shows that the result is independent of the permeability of the iron rod by applying Faraday's law of electromagnetic induction, $e=-d\phi/dt$, to the changing area A–B–C–D in his Figure 1 (page 256). So far, his method seems beyond reproach, but he also (equation 16) claims to prove that the "force per unit charge," $\mathbf{E}+(1/c)[\mathbf{v}\times\mathbf{B}]$, induced in the bar by its motion, is exactly the same as if the rod were of nonmagnetic copper, namely $(1/c)[\mathbf{v}\times\mathbf{B}_0]$, where $\mathbf{B}_0$ is the field at the remote end CD of his circuit and hence is the value of the uniform field in the absence of the iron. This result may be expressed in a different way: if a straight copper rod of length L moves with constant velocity $\mathbf{v}$ through a uniform magnetic field $\mathbf{B}_0$ (the rod, direction of motion, and field being mutually perpendicular), then theory tells us that a potential difference equal to B_0Lv will be induced between the ends of the rod. Doctor Slepian appears to claim to prove the same theoretical result for a rod made of iron. Is this correct? The problem is, of course, entirely theoretical, for any attempt to settle it by experiment would entail closing the circuit with other conductors and a measured value of the total electromotive force in the circuit will not give an answer to our question.

Referring to Doctor Slepian's Figure 1 on page 254, let $\mathbf{B}_0$ be the value of the magnetic induction, or flux density, of the uniform field in the absence of the iron rod. Let the actual value of the induction at any point, whether inside or outside the iron, be $\mathbf{B}$. Then if we define $\mathbf{B}_i$ as the component of $\mathbf{B}$ which is due to the magnetic atoms in the iron rod we have, in vector notation

$$\mathbf{B}=\mathbf{B}_0+\mathbf{B}_i \tag{1}$$

Then, when the rod moves, the value of $\mathbf{B}$ at any fixed point will change, but since $\mathbf{B}_0$ is uniform we have

$$\frac{d\mathbf{B}}{dt}=\frac{d\mathbf{B}_0}{dt}+\frac{d\mathbf{B}_i}{dt}=\frac{d\mathbf{B}_i}{dt} \tag{2}$$

Similarly, if $\mathbf{A}$ is the vector potential defined

by the relation curl $\mathbf{A}=\mathbf{B}$, we can also split $\mathbf{A}$ into components $\mathbf{A}_0$ and $\mathbf{A}_i$, where curl $\mathbf{A}_i=\mathbf{B}_i$ and

$$\frac{d\mathbf{A}}{dt}=\frac{d\mathbf{A}_i}{dt} \tag{3}$$

Now, assuming in the first instance that no electric charges are displaced on the moving rod, the total "force per unit charge" in it which is brought about by its motion will be equal to the "motional intensity" $[\mathbf{v}\times\mathbf{B}]$ plus the electric field (which acts equally on stationary or moving conductors) induced by the changing magnetic field at stationary points. Or, mathematically

$$\mathbf{F}=[\mathbf{v}\times\mathbf{B}]-\frac{d\mathbf{A}}{dt}=[\mathbf{v}\times\mathbf{B}]-\frac{d\mathbf{A}_i}{dt}=[\mathbf{v}\times\mathbf{B}_0]+[\mathbf{v}\times\mathbf{B}_i]+(\mathbf{v}\nabla)\mathbf{A}_i \tag{4}$$

where $(\mathbf{v}\nabla)\mathbf{A}_i=\Sigma v_x\frac{\partial\mathbf{A}}{\partial x}$

but

$$(\mathbf{v}\nabla)\mathbf{A}_i=\nabla(\mathbf{A}_i\cdot\mathbf{v})-[\mathbf{v}\times\text{curl }\mathbf{A}_i]=\nabla(\mathbf{A}_i\cdot\mathbf{v})-[\mathbf{v}\times\mathbf{B}_i]$$

so that

$$\mathbf{F}=\mathbf{v}\times\mathbf{B}_0+\nabla(\mathbf{A}_i\cdot\mathbf{v}) \tag{5}$$

(Dr. Slepian's factor $1/c$ is left out of the foregoing since it is not required if we use ordinary unit systems such as the meter-kilogram-second.)

The "force per unit charge" induced in the bar by the motion, therefore, consists of the two terms on the right-hand side of equation 5: the first term represents the resultant of two components, $[\mathbf{v}\times\mathbf{B}]$ which is the true "motional intensity" and acts only on the moving material, and a component $-[\mathbf{v}\times\mathbf{B}_i]$ or $[\mathbf{B}_i\times\mathbf{v}]$ which is that part of the induced electric field which may contribute to the electromotive force induced in the closed circuit. This latter component may, in general, result in the stationary wires *BC*, *CD*, and *DA* contributing to the induced electromotive force, but in the case of the rectangular circuit considered by Doctor Slepian this is not so, provided that the end *CD* is beyond the influence of the changing magnetic field. The sides *BC* and *DA* do not contribute since the velocity $\mathbf{v}$ is parallel to them. The second term in equation 5, $\nabla(\mathbf{A}_i\cdot\mathbf{v})$, is that part of the induced electric field which is the gradient of a potential function. Acting alike on stationary and moving conductors, it cannot contribute to the electromotive force induced in the closed circuit.

In general, however, the component $\nabla(\mathbf{A}_i\cdot\mathbf{v})$ must be included in the electric field $\mathbf{E}$ which appears in Doctor Slepian's equations 13, 14, 15, and 16. Thus, if the sliding bar is considered to be moving in isolation, the theoretical value of the potential difference induced between its ends, being equal to the line integral of $\mathbf{F}$, will not be equal to $\mathbf{B}_0Lv$ unless the term $\nabla(\mathbf{A}_i\cdot\mathbf{v})$ happens to be zero.

Now in the case considered, the lines of $\mathbf{A}_i$ happen to be at right angles to the velocity $\mathbf{v}$. This may be seen by considering Doctor Slepian's Figure 1 on page 254: if the lines of force there shown are considered to be lines of current flow through a long cylinder of greater conductivity than the medium in which it is immersed, then the magnetic lines of the field due to this current will be perpendicular to the paper, and parallel to the cylinder. The spatial relation between $\mathbf{A}$ and $\mathbf{B}$ is the same as that between $\mathbf{B}$ and $\mathbf{i}$ (current density), so that the lines of $\mathbf{A}_i$, the vector potential, in Figure 1 will also be parallel to the conducting rod and perpendicular to its direction of motion. Thus, the scalar product, $\mathbf{A}_i\cdot\mathbf{v}$, appearing in equation 5 is zero and we have

$$\mathbf{F}=\mathbf{v}\times\mathbf{B}_0 \tag{6}$$

We now have confirmed Doctor Slepian's equation 16, but his proof appears to lack validity owing to his unproved and, I think, erroneous statement that the side *AB* alone contributes to the integral. If the moving rod were to be placed obliquely across the fixed parallel sides of the circuit but still moved along the circuit, then $\mathbf{A}_i$ and $\mathbf{v}$ would not be perpendicular and their scalar product would not vanish.

The foregoing treatment is based on a straightforward development of the accepted physical theory of electromagnetism. If, however, we modify this in the way demanded by the transformations of the Theory of Relativity, a moving magnetized body develops, mathematically, an "apparent" molecular polarization whose effect is to cancel the second component of $\mathbf{F}$ in equation 5, and hence to make equation 6 generally true. A full explanation of this would be inappropriate in this letter, but it is hoped that Doctor Slepian will illustrate it in his later essays.

One further point: surely Doctor Slepian's result given in his equation 17 is true only if the rest of the conducting circuit has zero resistivity, for as it stands it means that the whole of the induced electromotive force is used up in sending the current through the resistance of the moving bar.

E. G. CULLWICK (M '33)

(St. Andrews University, Dundee, Scotland)

Two-Element Wattmeter

To the Editor:

In a Letter to the Editor (*EE, May '51, p 469*), Mr. Tschupp makes a theoretical review of the application of a 2-element wattmeter for determination of phase sequence, which scheme is feasible due to the fact that inherently the proper connection of such instrument demands one element operate at 30-degree lag and the other at 30-degree lead with unity power factor load. Hence, when either a leading or a lagging load is applied, the readings obtained by alternately disconnecting each of the potential circuits are different, for as the current in one element pulls closer into phase, the current in the other element leads or lags further out of phase. Proper evaluation of the individual wattage readings, as demonstrated, gives the phase sequence.

Practically, in the field, in the event a 2-element wattmeter is not already in the line, the same result may be obtained simply by using a single-phase wattmeter: where a high-voltage line is involved, necessitating the use of current and potential transformers, this method effects a considerable saving in equipment, setup time, wiring, and energy in transporting the equipment to and from the job.

It is only necessary to apply line current, say I_{1-0}, to the wattmeter, then take wattage readings alternately, using what would be E_{1-2} and E_{1-3}, if the rotation actually were 1-2-3. You will note that the first hook-up gives the "30-degree lag" and the second gives the "30-degree lead" connection to the wattmeter, at unity power factor. Since these are precisely the same conditions which prevail with a 2-element wattmeter, the individual wattage readings may be evaluated in the same way.

Relative to differentiation between inductive and capacitive loads, using a 2-element wattmeter, also mentioned by Mr. Tschupp, it might be of interest to know that for some 30-odd years Esterline-Angus Company has distributed curves or tables by means of which the exact power factor of a steady, balanced, leading or lagging load may be read, and from 'zero' to 'unity' power factor. The method is to divide the smaller wattage reading by the larger and apply the quotient to either the curve or the table.

In my opinion, schemes such as these are not stressed in most texts or handbooks because they are emergency, stop-gap methods, useful only in the absence of proper instrumentation.

THOMAS A. KENNY (M '50)

(P. O. Box 266, Summit, N. J.)

Aluminum Conductors for Aircraft

To the Editor:

In the December 1950 issue of *Electrical Engineering*[1] there appeared an interesting article on aluminum conductors. This confirms the great weight-saving which might be made if aluminum cables could be used in aircraft, and emphasizes that the chief obstacle to their being employed more widely is the difficulty of making a sound low-resistance joint at the termination.

While it is apparent from Mr. Schumacher's article that a drastic mechanical deformation may provide some solution to the problem of effecting a low-resistance

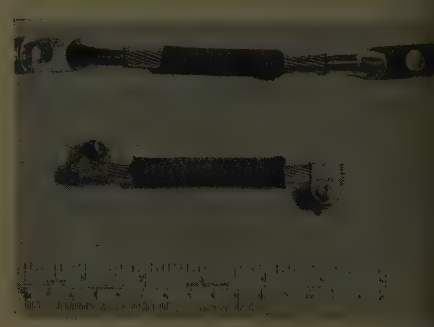


Figure 1. Comparison of soldered and clamped joints

contact, it would seem that a sounder technique might be based on the ultrasonic soldering apparatus that has recently become available.[2] Using solder containing 80 parts tin to 20 parts zinc in a bath excited by an ultrasonic transducer, we have tinned the end of a cable consisting of 37 strands of 0.064-inch

luminum wire, subsequently soldering it by the application of heat without ultra-onics) in a conventional tinned copper lug. The resistance of this joint was about 10 microhms, compared to 1,000 microhms for a circular clamp bolted on.

Since no absolute figures were given in Mr. Schumacher's digest, a direct comparison cannot be made with his results, but the improvement brought about by ultrasonic soldering is sufficiently striking to suggest that the "contact" resistance will not be higher than in the case of the indented terminal. The tinning operation would seem to be simpler and less critical and to give less danger of re-oxidation later.

Tensile tests were not made on these particular specimens. Experience with other samples has shown that lap joints in thin sheet can be made with strength comparable to that of the original aluminum.

REFERENCES

1. Aluminum Conductors for Aircraft, W. W. Schumacher. *Electrical Engineering*, volume 69, December 1950, page 1064.

2. Ultrasonic Soldering Irons, B. E. Noltingk, E. A. Neppiras. *Journal of Scientific Instruments* (London, England), volume 28, February 1951, page 50.

B. E. NOLTINGK and E. A. NEPPIRAS

(The Mullard Radio Valve Company Ltd., Salfords, Surrey, England)

NEW BOOKS

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

ASTM STANDARDS ON COPPER AND COPPER ALLOYS, sponsored by A.S.T.M. Committee B-5, January 1951. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 530 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $4.35. Containing 108 standards, this volume includes the latest specifications on cast and wrought copper and copper alloys, copper and copper alloy electric conductors, and nonferrous metals used in copper alloys. The specifications cover products as well as test methods and two recommended practices.

ANALYTICAL AND APPLIED MECHANICS. By G. R. Clements and L. T. Wilson. Third edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 463 pages, diagrams, tables, 9¼ by 6 inches, cloth, $5.50. A working text based on explicitly stated definitions and theorems, this book provides a rigorous discussion of the mathematical and physical theory of mechanics. Significant changes in this third edition include a somewhat briefer treatment of statistics; a greater emphasis on the motion of mass systems, with the plane motion of a rigid body as a special case; a study of mechanical vibrating systems with one degree of freedom and their electrical analogies; and a rearrangement of the material on simple and combined stresses, strains, and deflections in nonrigid bodies.

APPLICATIONS DE l'ÉLECTRICITÉ (Mément l'Électrotechnique, Tome IV). By A. Curchod and L. Vellard. Second edition. Dunod, Éditeur, 92 rue Bonaparte, Paris (VI), France, 1951. 491 pages, diagrams, charts, tables, 8¾ by 5½ inches, fabrikoid, 2,150 frs. Volume IV of this series covers in considerable detail some of the major applications of electric power: electric locomotives and electric traction practice; mechanical applications, such as drives for machinery; agricultural uses of various kinds; electrothermal devices, such as electric furnaces and welding equipment: and electrolytic applications including storage batteries.

(THE) BEHAVIOR OF ENGINEERING METALS. By H. W. Gillett. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 395 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $6.50. Designed to help non-metallurgists who must select metals and alloys for engineering uses, this book discusses the behavior of these materials rather than the theories that seek to explain their behavior. The first six chapters introduce basic concepts of metallurgy; the next nine deal with the behavior of each of the principal commercial metals and alloys; and the remaining chapters are devoted to special considerations that may influence the selection of metals and alloys. Bibliographies appear at the end of most of the chapters.

DIE CASTING. By H. H. Doehler. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 502 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $8.00. Of interest to metallurgists, equipment and product designers, production engineers, and students, this book discusses the present-day production methods and the design techniques of the entire field of die-casting. It describes the components and operations of the various types of die-casting equipment as well as every aspect of die construction and the requirements, composition, and applications of die steels and die-casting alloys. Also covered are the estimation of die-casting costs and safety in the die-casting plant. A final chapter supplies a glossary of terms.

DIESEL-ELECTRIC LOCOMOTIVE HANDBOOK —Electrical Equipment. 290 pages. DIESEL-ELECTRIC LOCOMOTIVE HANDBOOK—Mechanical Equipment. 262 pages. By G. F. McGowan. Simmons-Boardman Publishing Corporation, New York, N. Y., 1951. Illustrations, diagrams, charts, tables, 8¼ by 5½ inches, fabrikoid, $4.95 each. Basic reference books for enginemen, maintenance men, and other railroad personnel engaged in operating and maintaining diesel-electric locomotives, these books provide a survey of the theory and equipment used in this field. As indicated, one deals with aspects of electric equipment and the other with aspects of mechanical equipment. Direct information is given on the products of the major manufacturers.

DUNLAP'S RADIO AND TELEVISION ALMANAC. By O. E. Dunlap, Jr. Harper and Brothers, New York, N. Y., 1951. 211 pages, illustrations, 8¼ by 5¼ inches, fabrikoid, $4.00. This book is an almanac of facts, dates, and people in the history of radio and television. The chronological record begins with the first rudimentary discoveries in electronics in the 17th century and carries right up to 1950. It covers not only technical developments but the history-making events in such fields as international affairs, national politics, sports, aviation, and the arts. It includes a record of officials, past and present, of the various radio and television trade associations, institutes, and commissions.

DYNAMIC MOTION AND TIME STUDY. By J. J. Gillespie. Chemical Publishing Company, Brooklyn, N. Y., 1951. 140 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, $3.75. Relating work activity to work psychology, this book offers a solution to the problem of increasing efficiency without evoking the antagonism of the operator. Principles of motion study are included which provide a dynamic technique of motion simplification. A list of references is included at the end of the book.

ELECTRIC ILLUMINATION. By J. O. Kraehenbuehl. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1951. 446 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $8.00. This book presents the principles underlying the specification and design of electric lighting for commercial and industrial buildings. Reflecting the advances made since the first edition, changes include new material on glare and glare calculations, a treatment of the calculation of illumination from line and surface sources, consideration of louverall lighting systems, revision of the material on wiring and on economics of light production. New illustrations and appendices are included.

ELECTRIC CIRCUITS FOR ENGINEERS. By E. K. Kraybill. Macmillan Company, New York, N. Y., 1951. 212 pages, illustrations, diagrams, charts, tables, 9½ by 6¼ inches, linen, $3.85. In this book a broad picture of steady-state electric circuit theory is presented by the logical combination of a-c and d-c relationships into an integrated and unified whole. Special features are a correlation of electric phenomena with related phenomena in the general scientific field; use of standard terminology, definitions, and symbols; and use of actual values in the problems. A working knowledge of elementary differential and integral calculus and physics is essential.

ELECTRICAL AND RADIO DICTIONARY, including Symbols, Formulas, Diagrams, and Tables. By C. H. Dunlap, E. R. Haan, and L. O. Gorder. Fourth edition. American Technical Society, Drexel Avenue at 58th Street, Chicago 37, Ill., 1950. 133 pages, illustrations, diagrams, tables, 8½ by 5½ inches, linen, $1.75. In addition to definitions of terms used in electrical, radio, and television work, this book contains illustrations of standard symbols, sample circuits, wire and insulation tables, and other useful data.

JANE'S ALL THE WORLD'S AIRCRAFT 1950–51. Compiled and edited by L. Bridgman. McGraw-Hill Book Company, New York, N. Y. 536 pages, illustrations, diagrams, tables, 13 by 8 inches, linen, $20.00. This standard handbook contains up-to-date and authoritative data on the civil and military aircraft of 62 nations. In this 41st edition several new sections of information have been added, and hundreds of new illustrations. The section on military aviation is fully revised up to mid-1950 to include details on the recently organized air forces of Hungary, Israel, Indonesia, Lebanon, and the Philippine Republic. A new feature is a list of first flights made within the past year.

PERSONNEL HANDBOOK. Edited by J. F. Mee. Ronald Press Company, New York, N. Y., 1951. 1,167 pages, illustrations, diagrams, charts, tables, 7½ by 4¾ inches, fabrikoid, $10.00. This handbook provides a comprehensive reference guide to the best practice in the field of personnel and industrial relations. It presents guiding principles, factual data from experience, specific recommendations, criteria for evaluation, standards for comparison, step-by-step procedures, and case examples from practice. Specific practical problems which arise in the organization and implementation of training or safety programs, proper employee recruiting and selection, preparation for labor contract negotiations and administration of contracts, testing, merit rating, and so forth, also are covered.

PLANT LAYOUT PLANNING AND PRACTICE. By R. W. Mallick and A. T. Gaudreau. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1951. 391 pages, illustrations, diagrams, charts, maps, tables, 9¾ by 6¼ inches, linen, $7.50. Written for the administrative executive and plant engineer, this book is devoted to the principles and practice of planning, design, presentation, and economics of plant layout projects. It covers both relayouts and new plants with data on designing and evaluating all plant facilities and services. Plant location, building architecture, and construction engineering are not discussed. A bibliography divided into subjects covers both the topics covered and the three aforementioned topics which are not treated.

PROPAGATION OF SHORT RADIO WAVES. (Massachusetts Institute of Technology, Radiation Laboratory Series, Volume 13). Edited by D. E. Kerr. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 728 pages, illustrations, diagrams, charts, maps, tables, 9¼ by 6 inches, cloth, $10.00. This volume treats the phenomena associated with the propagation of short radio waves between terminal points, whether they be the radar antenna serving a dual purpose or the antennas of a communication system. It presents a summary of the state of knowledge in the microwave-propagation field at the close of the war. The eight chapters cover general considerations, theory of propagation in a horizontally stratified atmosphere, meteorology of the refraction problem, experimental studies of refraction, reflections from the earth's surface, radar targets and echoes, meteorological echoes, and atmospheric attenuation.

STORY OF METALS (Series for Self-Education). By J. W. W. Sullivan, published jointly by American Society for Metals, Cleveland, Ohio, and Iowa State College Press, Ames, Iowa, 1951. 290 pages, illustrations, diagrams, charts tables, 7¾ by 5 inches, fabrikoid, $3.00. A simply written, historical account of the gaining, working, and use of metals from the earliest times to the present. Review questions are provided at the end of each chapter, and the book includes a table of all the metallic elements and a glossary of selected technical terms.

THEORY AND APPLICATION OF ELECTRICAL ENGINEERING. By E. W. Schilling. International Textbook Company, Scranton, Pa., 1951. 402 pages, illustrations, diagrams, charts, tables, $6.50. Placing

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ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

special emphasis on circuit theory and machinery, this text covers more topics than are usually contained in a fundamental treatment of this subject. Among the features of the book are unbalanced 3-phase load coverage; motor selection for duty-cycle operation; a mathematical discussion of the current growth in an inductance-reactance circuit; discussion of radio interference; coverage of automatic starters for d-c motors; and instruction on rate structures. Electronics, illumination, and storage batteries also are considered.

PRACTICE OF LUBRICATION. By T. C. Thomsen. Fourth edition revised. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 617 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$8.00. This text provides a comprehensive coverage of the origin, nature, testing, selection, application, and use of all types of lubricants. New material presented in this fourth edition includes additives, the lubrication of aeroengines and aircraft accessories, the use of fabric bearings in steel mills, and the use of other types of bearings, synthetic oils, new solvent-refining processes, and developments in lubricant manufacture.

QUALITY CONTROL: Principles, Practice, and Administration. By A. V. Feigenbaum. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 443 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, linen, \$7.00. This book presents quality control as a business method for actual plant application. In four parts, the first part discusses, from a general management standpoint, the nature and potential uses of quality control, activities, organization, and results; the second covers the statistical tools required; the third considers the application of quality control in engineering, purchasing, incoming inspection, manufacturing, sales, and so forth; and the fourth develops the procedures for actually instituting a practical program.

SOURCEBOOK ON ATOMIC ENERGY. By S. Glasstone. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England, 1950. 546 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$2.90. This book surveys the important facts about the history, present status, and possible future of atomic science. It considers peacetime and wartime applications. Beginning with the earliest theories of the atom and its structure, the growth of thought and knowledge, the development of theories, and the discovery of the phenomenon of radioactivity are described. Atomic particles, modern instruments, and the release of atomic energy are treated. Radiation protection and health physics also are considered.

SYMPOSIUM ON ULTRASONIC TESTING (Special Technical Publication Number 101), presented at the 52nd Annual Meeting, American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1951. 133 pages, illustrations, charts, tables, 9 by 6 inches, paper, \$2.00 (to A.S.T.M. members, \$1.50). The ten papers and discussions included in this book represent a summary of the history, theoretical aspects, basic principles of practical testing, and practical applications for the ultrasonic testing of materials. Several of the papers include lists of references, and one bibliography of 342 references on the inspection, processing, and manufacturing control of metals by ultrasonic methods is included.

TECHNICAL OPTICS, Volume II. By L. C. Martin. Pitman Publishing Corporation, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 344 pages, illustrations, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, linen, \$7.50. This new and revised edition of Volume II of the author's "Introduction to Applied Optics" deals with the construction and performance of optical instruments. Reflecting the advances made during the last few years, new material is included on the theory of phase-contrast microscopy, Schmidt cameras, the problems of aspheric surface optics, and other new topics. Emphasis is on optical concepts rather than a rigorous mathematical treatment.

THÉORIE, FONCTIONNEMENT ET CALCUL DES MACHINES ÉLECTRIQUES, Tome I. Circuit magnétique—Machines à courant continu. By A. Guilbert, preface by A. Mauduit. Dunod, Éditeur, 92 rue Bonaparte, Paris (VI), France, 1951. 606 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, linen, 2,760 frs. This first volume of a set on the theory, operation, and design of electric machinery deals only with d-c machines. Following information on electromagnetic fundamentals and the general characteristics of d-c circuits and windings, detailed treatments of d-c generators and motors are given. Phenomena auxiliary to the operation of d-c machinery are discussed, and the last chapter consists of notes on electrical design calculations.

THEORY AND APPLICATION OF INDUSTRIAL ELECTRONICS (McGraw-Hill Electrical and Electronic Engineering Series). By J. M. Cage and C. J. Bashe. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 290 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by $6^1/_4$ inches, fabrikoid, \$4.75. Written primarily for college graduate and undergraduate courses in industrial electronics, this text covers the electronic instrumentation of both electrical and nonelectrical quantities, electronic control including servomechanisms, and electronic power including d-c power, induction heating, and dielectric heating. Emphasis is on fundamental principles and their applications. Photographs and drawings are used liberally to illustrate specific points, and problems at the end of the chapters combine theory with simple workable applications.

3100 NEEDED INVENTIONS. By R. F. Yates. Wilfred Funk, Inc., 381 Fourth Avenue, New York 16, N. Y., 1951. 336 pages, $7^1/_2$ by 5 inches, cloth, \$2.95. The more than 3,000 suggestions are broadly classified in chapters or chapter sections under a wide variety of headings. In addition to the great general group of suggestions, a list of current special problems of particular interest for national defense is included. The early chapters also provide some discussion of the field and of methods of inventive procedure.

WATER TREATMENT FOR INDUSTRIAL AND OTHER USES. By E. Nordell. Reinhold Publishing Corporation, New York 18, N. Y., 1951. 526 pages, illustrations, diagrams, charts, maps, tables, $9^1/_4$ by 6 inches, linen, \$10.00. This comprehensive book on industrial waters should be of practical value to all whose work involves their use. The first four chapters are devoted to impurities in water supplies and how they can be eliminated or reduced. Chapter 5 concerns industrial water requirements and water-treatment practices. The next two chapters describe the problems and practices relating to boiler feed waters and cooling waters. The remainder of the text covers the different processes and equipment used in treating water. The appendix contains 43 tables of conversion factors and equivalents and three curves for use in calculations.

WAVEGUIDE HANDBOOK. Edited by N. Marcuvitz. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 428 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches cloth, \$7.50. This book presents in compact form all currently available data, and some experimental data on the properties of microwave transmission lines, microwave circuit elements, and of certain other microwave structures. Data are given in the form most easily applied in practical circuit design. Theoretical results are stated in analytical form, and numerous graphs present results in numerical form. Textual material is restricted to that needed to explain the form of presentation and, in some cases, to indicate methods of application.

PRODUCTIVITY, SUPERVISION AND MORALE IN AN OFFICE SITUATION. Part I. By D. Katz, N. Maccoby and N. C. Morse; published by University of Michigan, Institute for Social Research, Survey Research Center, Ann Arbor, Mich., 1950. 84 pages, tables, $8^1/_2$ by $5^1/_2$ inches, paper, \$2.00. This report presents the findings of a research project of the Office of Naval Research on group productivity as observed in a business office. It is the first in a proposed series on this subject. This report outlines the study plan, the methods used to obtain data, and the results of the study.

PAMPHLETS

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

National Electrical Code 1951. The 1951 edition contains changes and includes one entirely new article on induction and dielectric heat generating equipment. The Code is used as a basis for safe electrical wiring and installations in most of the 48 states. The National Fire Protection Association (NFPA) is sponsor of the Code and has been for the past 40 years. Containing 415 pages, it is available from the National Fire Protection Association, Publication Services Department, 60 Batterymarch Street, Boston 10, Mass., at \$3.00 per copy. A pocket edition of the Code is available from the same source at \$1.00 per copy.

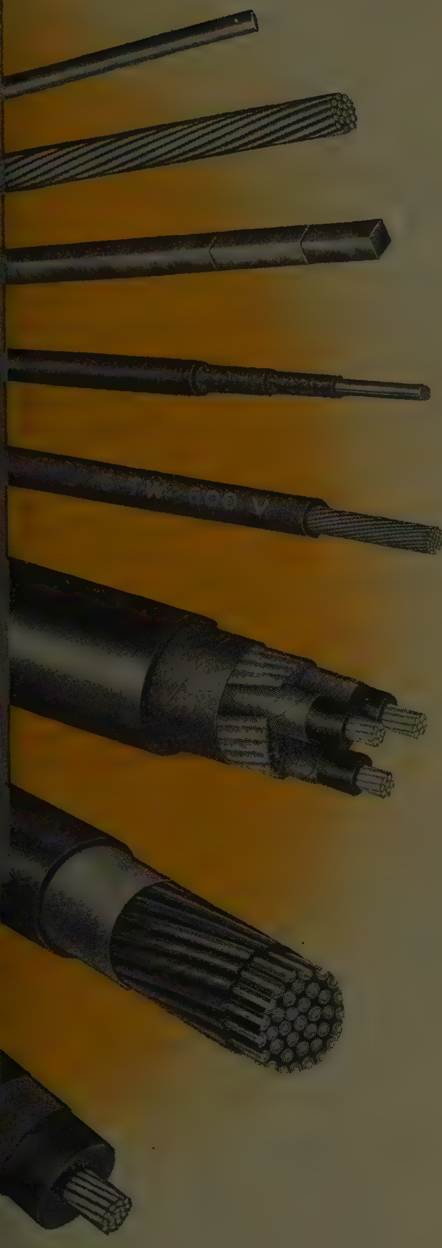
Review of Current Research. Published by the Engineering College Research Council (ECRC) of the American Society for Engineering Education, this book outlines the policies and activities of engineering research in 91 colleges and universities holding membership in ECRC. A brief digest of policies which govern research projects and contracts at each institution is given, and also the number of personnel engaged in research activities, the annual expenditures, and special conferences and a short course of interest to research workers. Copies are available at \$2.25 each, and may be obtained from the Secretary of the Engineering College Research Council, Room 7-204, 77 Massachusetts Avenue, Cambridge 39, Mass.

Tensile Recovery Behavior of Textile Fibers. This report, prepared by the Army Quartermaster Corps, presents an account of systematic recovery tests of samples representing 16 different textile fiber materials. The materials are compared as to the percentage of elongation which recovers immediately; that which recovers after a defined period of time; and that which remains permanently. Illustrated. Available at \$1.50 per copy from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

Lighting and the Nation's Welfare. This report is divided into five sections: Production Lighting; Office Lighting; Protective Lighting; Public Safety Lighting; and Education Lighting. In addition to complete statistics on the effects of lighting, this report contains several comprehensive charts and graphs illustrating many of the important points brought out by this study. It is available for 25 cents per copy from the National Information Committee on Lighting, 1410 Terminal Tower, Cleveland, Ohio.

Studies on Synthetic Lubricant Oils. This report, prepared by the Defense Department's Central Air Documents Office, is a description of studies in this field carried on by Germany's I. G. Farben. Available at 50 cents per copy from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

You've Helped Rome Cable Make The Years Count



Fifteen years ago this July, we made our first shipment of wires and cables to the electrical industry. Your ready acceptance of Rome Cable products since that time has more than justified our confidence in that first shipment.

Today, electrical power surges through Rome wires and cables of many types, in many places . . . powering vital industry, lighting cities, safeguarding life, bringing convenience and comfort to homes throughout the land.

Burrowing deep for vital minerals, carrying heavy power loads from city to city, turning the wheels of the nation's industry . . . Rome wires and cables are unfailingly at work.

When the farmer flips his barn switch for that 4 A.M. milking . . . when a hundred and one electrical conveniences are called into use . . . Rome wires and cables are at work.

When television gives you a ringside seat, when an electric mixer whips up a cool summer drink . . . or, a neon sign steers you toward a highway hamburger . . . Rome wires and cables are at work.

Yes, even when a telephone voice directs an artillery barrage into Korean hills . . . the vital thread of communication may well be a Rome product. For, today Rome Cable is, again, producing for defense.

So, for fifteen years Rome Cable has steadily grown in meeting your ever-increasing needs. Rome research and engineering have designed better cables, have maintained dependable, high quality . . . *to give you of the electrical industry only the best.*

At this milestone in our progress, we, again, dedicate our future to ever higher quality of product and the desire to serve *you who have made these years count.*

ELECTRICAL CONDUCTORS AND STEEL CONDUIT OF *BETTER QUALITY*

It Costs Less To Buy the Best

ROME CABLE Corporation
ROME · NEW YORK
and
TORRANCE · CALIFORNIA

ROME CABLE ROME, N.Y.

INDUSTRIAL NOTES ....

Alcoa Promotes Top Executives. Roy A. Hunt, President of the Aluminum Company of America since 1928, has been named Chairman of the Executive Committee; I. W. Wilson, Senior Vice-President, was made President; and Leon E. Hickman has been named Vice-President and general counsel. Arthur V. Davis continues as Chairman of the Board.

Skinner and Rich Appointed Vice-Presidents of Philco. James M. Skinner, Jr., and Ray A. Rich have been made Vice-Presidents of the Philco Corporation.

Servomechanisms, Inc., Relocates. Servomechanisms, Inc., presently at Old Country and Glen Cove Roads, Mineola, L. I., N. Y., has relocated its main office and home plant to new quarters at Post and Stewart Avenues, Westbury, L. I., N. Y.

G-E Expands Jet Engine Program. The aircraft gas turbine divisions of the General Electric Company have taken an option to lease manufacturing space (the vacant Gaymont woolen mill) in Ludlow, Vt., as part of their expanded jet engine production program. Headquarters for the divisions will ultimately be located at the General Electric plant in Lockland, Ohio, where a vast aircraft jet engine and turboprop test, development, and production center is being established to meet the military needs for the company's aircraft engines. The company's current production model is the *J-47*, which powers the North American F-86 "Sabre" and the 6-jet Boeing B-47, the Republic XF-91 interceptor, Martin XB-51 3-jet bomber, North American F-86D interceptor, and the Convair B-36 intercontinental bomber, with four *J-47*'s as auxiliary power units.

Union Carbide and Carbon Appointments. Fred H. Haggerson, President of the Union Carbide and Carbon Corporation, has also been elected Chairman of the Board of Directors; Morse G. Dial has been named Executive Vice-President; and Dr. G. O. Curme, Jr. has been elected Vice-President in charge of research.

Leeds and Northrup's Boston Office Moves. The Boston office of the Leeds and Northrup Company has been moved to 430 Lexington Avenue, Auburndale, Boston 66, from its former location, 31 St. James Avenue.

Dr. Thomas Elected President of Monsanto. Dr. Charles Allen Thomas, formerly Executive Vice-President, has been elected President of the Monsanto Chemical Company. Doctor Thomas replaces William M. Rand, who has retired.

Roller-Smith and Elpeco Divisions Transferred. The Realty and Industrial Corporation has transferred the business and assets of its Roller-Smith and Elpeco Divisions to the newly formed Roller-Smith Corporation. Business will be maintained at its present locations, 1000 North 8th Avenue and 1756 West Market Street, Bethlehem, Pa., and 106 East Walnut Street, Allentown, Pa.

Du Mont Appointment. Walter C. Hustis has been named sales representative, New England territory, electronic parts division, Allen B. Du Mont Laboratories, Inc.

Moore Elected Executive Vice-President of Lear. Paul Moore has been elected Executive Vice-President and general manager of Lear, Inc.

Research Corp. Names Two Vice-Presidents. James M. Knox and Carl W. Hedberg have been made Vice-Presidents of the Research Corporation. Mr. Knox, the financial officer, will make his headquarters at the New York office; Mr. Hedberg will continue in charge of operations at the Bound Brook, N. J., plant.

Sprague Acquires New Facilities. The Sprague Electric Company has purchased part of the main plant of the former Holden-Leonard woolen mill in Bennington, Vt., to expand its facilities for the manufacture of high-temperature magnet wire.

Changes in Top Officers Made at Babcox and Wilcox. The Babcock and Wilcox Tube Company has announced the election of Luke E. Sawyer, formerly Executive Vice-President, to President; Alfred Iddles, formerly President, was made Chairman of the Board; Isaac Harter, formerly Chairman, was named a consultant to the company; and Edward A. Livingstone was made a Vice-President.

Allis-Chalmers Appointment. J. F. Roberts has been made director of engineering, and R. C. Allen consulting engineer of the general machinery division of Allis-Chalmers Manufacturing Company.

Westinghouse Elects Two Vice-Presidents. E. W. Ritter, manager of the Westinghouse Electric Company's electronic tube division, has been named a Vice-President of the company, and E. V. Huggins has been elected Executive Vice-President of the Westinghouse Electric International Company, the foreign trade subsidiary of Westinghouse. William G. Marshall, Vice-President in charge of industrial relations for 17 years, has retired. The company has also announced the appointment of J. H. Green as manager, photoflash lamp plant, Bowling Green, Ky.

United States Steel Appointment. James H. Duff has been made assistant manager of sales of the New York district sales office of the United States Steel Company.

(*Continued on page 28A*)

...000 kva 3 phase, 60 cycle, 55° C rise, positive pressure ...s equipped outdoor transformers installed by Consumers Power Company at Pontiac substation. Soon to be added is a 30,000 kva Allis-Chalmers power transformer at Erie.

(*Continued from page 16A*)

NEW PRODUCTS . .

High-Power Transmitting Tube. The Amperex Electronic Corporation, 25 Washington Street, Brooklyn 1, N. Y., has announced development of a new high-power air-cooled transmitting and power tube, type *AX-9906R/6078*, with a plate dissipation of 45 kw and a weight of only 66 pounds. The tube's high ratio of plate dissipation to weight is due to the fact that it employs high efficiency radiator fins and a new type of air flow chamber. High velocity air is diverted in the assembly into a number of parallel paths, thus minimizing the total pressure. Designed for high-power transmitter and industrial applications, the triode produces an output of 108 kw at 15 megacycles and is intended for operation up to a maximum frequency of 30 megacycles. Complete information is available from the company.

Pneumatic Timer with Invertible Magnet. Designed for timing machine tool cycles, conveyor systems, and similar industrial operations, the Square D class-*9050* type-*R* pneumatic timing relay has a new invertible magnet that increases its adaptability to user's requirements. Depending upon the position of the a-c actuating magnet, contacts operate with delay either after energization or after de-energization of the magnet. The timing range is adjustable from 0.2 second to 3 minutes. Operation is based on the principle of air transfer between two chambers through a restricted orifice. Contacts have pilot duty ratings up to 600 volts alternating or direct current. Bulletin *9050-RQ*, available from the Square D Company, 4041 North Richards Street, Milwaukee 12, Wis., contains more complete details on the timer.

Electronic Brain. The Computer Corporation of America, 149 Church Street, New York 7, N. Y., has introduced a low-cost, compact, integro-differential analyzer, nicknamed Ida. Ida can solve qualitative and quantitative studies in chemistry, mechanical engineering, aerodynamics, nucleonics, thermodynamics, servoanalysis, and network analysis. It solves linear differential equations with constant coefficients up to the eighth order. Eight initial conditions may be set into the problem. Solutions are recorded in graphic form on a 2-channel oscillograph. All computed quantities can be recorded, two at a time. Any computed quantity can also be viewed on a 2-channel, magnetic cathode-ray oscilloscope while being recorded. Other features are eight precision integrating capacitors, with a tolerance of ± 1 per cent, 23 10-turn, helical-unit potentiometers with linearity tolerances of ± 0.5 per cent (eight of these potentiometers may be used as initial-condition potentiometers), 20 high-gain interchangeable, plug-in, d-c amplifiers, using both positive and negative feedback, and a power supply which provides voltages regulated to better than 0.1 per cent. This regulation is maintained under simultaneous variations of load (from

(*Continued on page 34A*)

at this Eastern Plant

Modern G-E Metal-clad Switchgear now installed at he Traylor Company provides greater safety because ll parts are completely enclosed. For greater protection against short circuits, separate circuits are isolated in individual compartments. Circuit breakers may be easily removed for inspection, with protection for personnel. Power is distributed from this unit at 2400 volts, replacing the old 240-volt distribution system.

Load-center Unit Substation eliminates long low-voltage feeders—saves copper. 2400-volt power is eceived at this load-center unit substation and stepped down to utilization voltage on the factory floor. Because the substation is located close to the machines it serves, low-voltage feeders are short, saving copper and giving better voltage control. Discarded cable previously used for low-voltage distribution is shown at left.

GENERAL ELECTRIC

854-35

(*Continued from page 34A*)

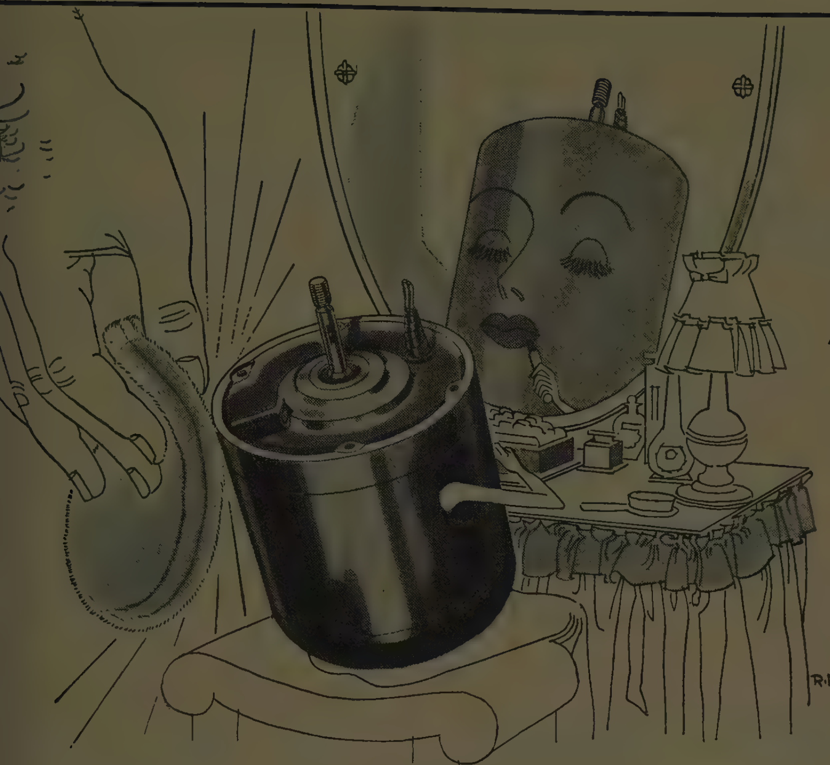
no load to full load) and of line (from 105 to 135 volts). Input is 110 volts, 50 to 60 cycles alternating current. Any further details may be obtained from the company.

Electrical Steel. The Armco Steel Corporation has developed a new thin electrical steel known as TRAN-COR T-O-S, which can be operated at inductions 20 per cent higher than any nickel-iron alloy. Intended for use in wound-type transformers and reactors which operate at 400 cycles, the new material was developed under a contract with the Bureau of Aeronautics of the Navy Department to permit miniaturization and reduction in weight of airborne electric equipment. Minimum permeability at 18 kilogausses is 1,800. TRAN-COR T-O-S is an iron-silicon alloy with a density of 7.65 grams per cubic centimeter, a volume resistivity of 47 microhm-centimeters or 282 ohms per mil feet, and a lamination factor of 95 per cent solid. More complete information may be obtained from the Armco Steel Corporation, 703 Curtis, Middletown, Ohio.

Temporary Load Break. The temporary load break, load pick-up switch, a new A. B. Chance Company product, provides a simple means for removing taps from conductors under load conditions, where there are no reclosers or circuit breakers, without pitting or burning the conductors or clamps and without drawing long arcs that hazard phase-to-ground or phase-to-phase faults. When loaded branch circuits that have been out of service must be reconnected to main line conductors, the switch can be used as a pick-up device, giving the same protection to line and equipment. The device combines a disconnect switch and flexible link connection. After the switch blade is pulled, the link connection is broken by tripping a trigger to release the link intact. Cutouts may be opened safely on loaded circuits by jumping around them with the load switch jumper, to by-pass the circuit while the cutout is opened manually—then breaking the circuit by pulling the switch trigger. Disconnecting capacitors, or opening disconnect or sectionalizing switches under conditions that might produce long, uncontrolled arcs, may also be accomplished with this switch. Any further information may be obtained from the A. B. Chance Company, Centralia, Mo.

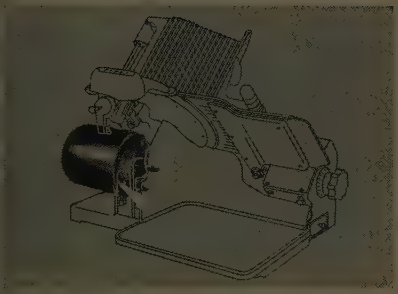
100-Volt D-C Capacitors.* A line of 100-volt d-c capacitors, with double the capacitance designed into the same capacitor space, has been announced by the General Electric transformer and allied product divisions at Pittsfield, Mass. For applications where an expected life of 1,000 hours is satisfactory, the rating can be increased to 150 volts, and temperatures to 40 degrees centigrade. There is negligible change in capacitance from −40 degrees centigrade to 105 degrees centigrade, and the units give full life expectancy at temperatures as low as −55 degrees centigrade. These thin-paper, thinfoil capacitors will pass signal voltages approaching zero, and

(*Continued on page 38A*)



Want to "make up" a motor to show off your product?

JACK & HEINTZ does it!



J & H specially designed motor for food slicer manufacturer. Top-quality parts and precision workmanship mean years of trouble-free service life.

Here, stator laminations for a motor are punched on a high-speed automatic press, typical of the kind of equipment that enables J & H to mass-produce both standard and custom-built motors.

J & H engineers specialize in designing power packages to harmonize with the products they serve. For example, take the ¼-HP motor we designed for a streamlined food slicing machine. Dynamic balancing to $\frac{1}{20}$ ounce-inch and unusual design features assure exceptionally smooth, quiet operation. Its short, clean-lined housing blends with our customer's modern, well-designed product.

Making *Rotomotive* devices, tailored to fit, is the kind of job we do best. Whether your motor requirements call for modern appearance or unusual compactness, special mountings or unique wiring, large or small quantities—or any combination of these—just remember, Jack & Heintz *does it!*

For information, write Jack & Heintz . . . Cleveland 1, Ohio.

JACK & HEINTZ *Rotomotive* EQUIPMENT

means electrical, hydraulic or mechanical devices designed to solve unusual problems of developing power, controlling it, or using it.

(*Continued from page 34A*)

can also be used in low-voltage a-c circuits under many conditions. The General Electric Company, Schenectady 5, N. Y., will supply any additional details upon written request.

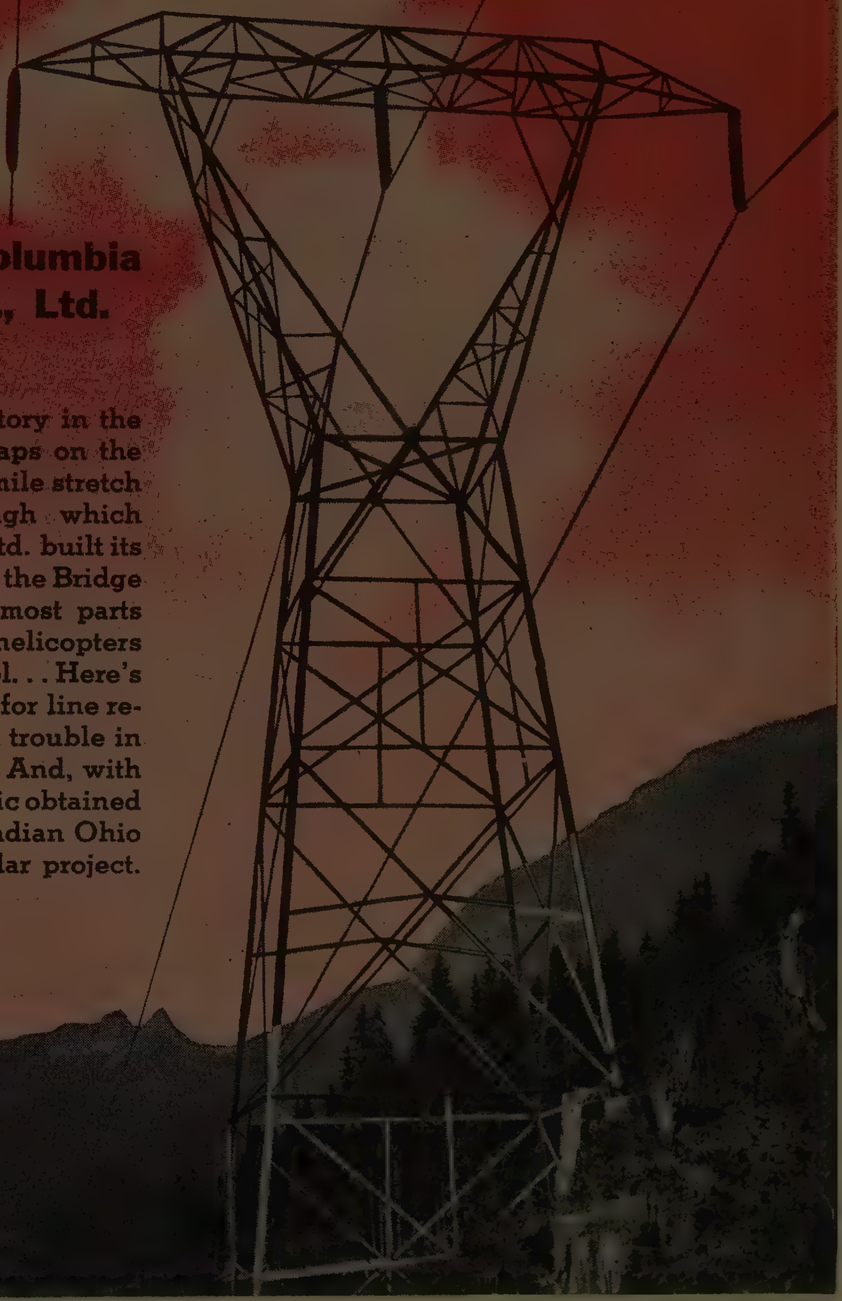
225-Reactive-Kva Capacitor Bank. The Cornell-Dubilier Electric Corporation, 1,000 Hamilton Boulevard South, South Plainfield, N. J., has announced development of a 225-reactive-kva switched power-factor improvement capacitor bank, which is designed for operation on 2,400 to 4,160 3-phase distribution circuits. Two of these units may be installed from a common cross arm, permitting short symmetrical connections and maximum accessibility for service and maintenance. Arrangement of the electrically operated oil switch and the capacitor units provides a weight balanced assembly, mounted in a galvanized structural steel hangar. Further information is available from the company.

Motor Starters. The new Clark *CY-2* starter for a-c motors introduces a new arc-interrupting principle by the combined use of strong multi-turn magnetic blowouts with twin break contacts. A steel case, enclosing each arc chamber, carries the flux. The arc is extinguished by applying the effect of the blowout coil concentric with the contact. The steel arch chamber and center stud form the magnetic circuit around each contact. The magnetic field is concentrated in a cone from the steel center stud supporting the upper contact, to the steel rim in the lower arc shield surrounding the lower contact. Two different actions occur, changing each half-cycle with the reversal of the current. In one current direction the arc is forced to the outer edge of the upper contact, lengthened, and rotated. In the other, the arc is rotated and forced to the middle of the upper contact. In each case, the magnetic field tends to extinguish the arc, either by lengthening it or confining it. The most important action is the constant moving of the arc. In its forced rotation, it must continually move from a hot spot to a relatively cool spot, and the result is effective arc interruption. No carbonizing of insulating material can occur because all parts in the arc chamber are copper, brass, and steel. The top of the arc chamber is closed, thus preventing accumulation of the ionized gases between the wiring terminals. This factor minimizes phase to phase failures. Mr. E. C. Roberts, Advertising Manager, The Clark Controller Company, 1146 East 152nd Street, Cleveland 10, Ohio, will answer any inquiries on the starter.

Ionization Tester. A new nondestructive method of testing electrical insulation and cables has been introduced by the British Electronic Group, 366 Madison Avenue, New York 17, N. Y. The Airmec 5-kv ionization tester type *732* operates from 100–130- and 200–250-volt 50-cycle-per-second mains. Consumption is approximately 50 watts. A direct voltage con-

(*Continued on page 44A*)

The best way to deal with insulator trouble here is NOT TO HAVE IT!



That's Why British Columbia Electric Railway Co., Ltd. Chose O-B

Reputed to be the roughest territory in the Dominion of Canada, and perhaps on the American Continent, is the 130-mile stretch northeast of Vancouver through which British Columbia Electric Co., Ltd. built its new 230-kv transmission line to the Bridge River Hydro plant. Access to most parts of the line is so difficult that helicopters are used for inspection and patrol... Here's no place to send a service truck for line repairs. The best way to deal with trouble in this territory is *not to have it!* And, with this thought in mind, B. C. Electric obtained suspension insulators from Canadian Ohio Brass Co., Ltd. for this spectacular project.

Ohio Brass

MANSFIELD · OHIO

(*Continued from page 38A*)

tinuously variable from 250 to 5,000 volts is provided by a high impedance source, and this voltage is applied to the insulation of the component under test. The ionization currents which occur within the insulation when the voltage is raised beyond a certain value are amplified and used to provide an audible indication by means of a loudspeaker. Thus the threshold voltage level at which ionization commences is immediately apparent, and the test may be discontinued at any point before actual breakdown occurs. Leakage resistances of the order of 50 megohms and less are indicated visually by means of the opening of a cathode-ray indicator and the fall in reading of the voltmeter. Since the working life of any insulation is considerably shortened by continuous subjection to a voltage sufficient to cause ionization, the maximum safe working voltage of any component can be immediately ascertained by this instrument without danger to either the component or the test operator.

Further details may be obtained from the company upon request.

TRADE LITERATURE

Class-Room and Student Aids. The Advertising Department of Sylvania Electric Products, Inc., Emporium, Pa., has issued a bulletin which lists Sylvania technical publications, such as radio instruction course charts and lesson folders, radio symbols charts and a guide, a technical tube manual, a germanium diode book, an Ohm's law chart, tube characteristics folders, a television servicing book, and others. Many of these publications, designed for the engineering student, are available without charge. Copies of the bulletin listing these class-room aids are available upon request to the company.

Better Industrial Lighting. A new lighting-at-work bulletin has been issued by the Westinghouse Electric Corporation. Aimed at the industrial plant operator, this booklet analyzes the three modern light sources—fluorescent, mercury vapor, and incandescent. Copies of *B-4727* are available from the company at Box 2099, Pittsburgh 30, Pa.

Fixed Composition Resistors. The International Resistance Company, 401 North Broad Street, Philadelphia 8, Pa., has made available catalogue bulletin *B-1*, which contains data on characteristics and specifications of advanced type *BT* fixed composition resistors for 1/3, 1/2, 1, and 2 watts. It may be obtained upon request.

Testing Instruments. Bulletin *GEA-5459* is a buyer's guide for testing instruments. It may be obtained from the General Electric Company, Schenectady 5, N. Y.

Welding Design Manual. The third 50-page edition of Eutectic's welding design manual, which includes new articles on

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joint preparation by means of electric arc, design information, new 1951 welding alloy developments, and chemical welding aids, is available from the Eutectic Welding Alloys Corporation, Department P, 40-40 172nd Street, Flushing, N. Y.

Electrical Insulation. A series of eight product bulletins (numbers *250*, *400*, *511*, *527*, *680*, *680A*, *750*, *800*) covering heat resistant class-H silicone electrical insulation materials has been published by the Insulation Manufacturers Corporation, 565 West Washington Boulevard, Chicago 6, Ill. All bulletins may be obtained upon request.

Roller Bearing Engineering. SKF Industries, Inc., Philadelphia 32, Pa. has made available their 270-page book, "Ball and Roller Bearing Engineering," for the special price of $1.75. The text covers in technical detail such subjects as bearing types and nomenclature, capacities, selection, design, installation, maintenance, causes of failures, and load calculations.

Protection of Motors. Co-ordinated protection—interlinked protection of circuits, motors, and personnel—is explained in a new high-voltage combination-starter booklet, *DB-4673*, available from the Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa.

Motor Control. A 92-page illustrated catalogue containing information and descriptions of Allen-Bradley motor controls has been announced as available from the Allen-Bradley Company, 136 West Greenfield Avenue, Milwaukee 4, Wis.

Vacuum Calculator. A slide rule, designed for quick calculations in vacuum research and processing work, has been developed by the F. J. Stokes Machine Company, 5900 Tabor Road, Philadelphia 20, Pa. The slide rule will determine needed pump capacity to evacuate a given volume to a specified vacuum in a given time, and the time required to reach a specified vacuum in a given volume with a pump whose capacity is known. It will also determine vapor pressures of water at various temperatures, and capacities of round tanks in both cubic feet per foot and gallons per foot. The Stokes slide-rule vacuum calculator is available upon request.

Flame Failure Protection. "Protectoglo Combustion Safeguard for Industrial Gas-Fired and Oil-Fired Burners," catalogue *9601*, is a 32-page manual on flame failure protection for industrial applications. Copies may be obtained from the Minneapolis-Honeywell Regulator Company, Industrial Division, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Sprague Bulletins. The Sprague Electric Company, North Adams, Mass., has issued

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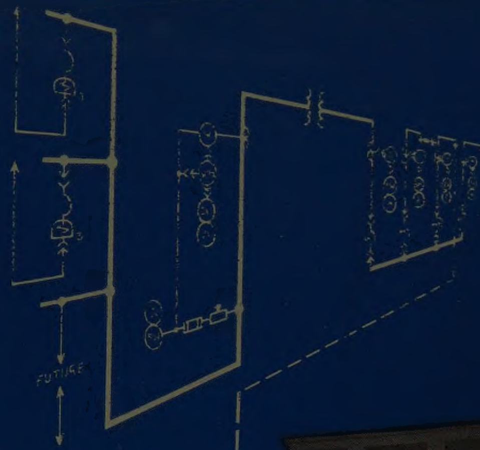

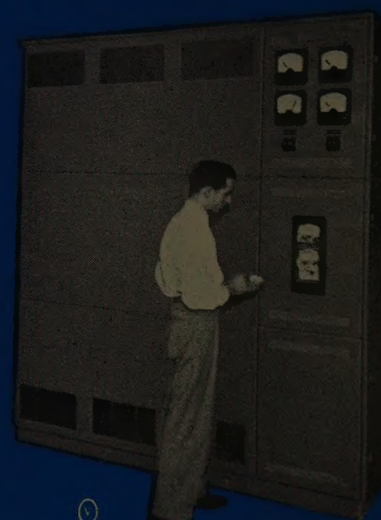

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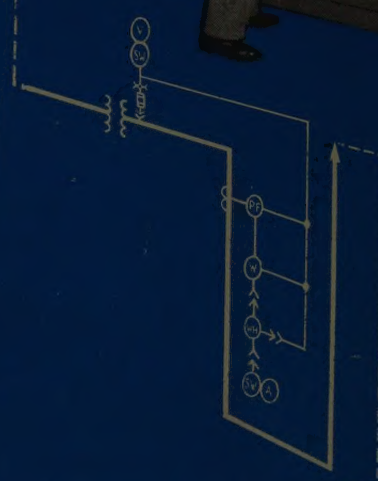
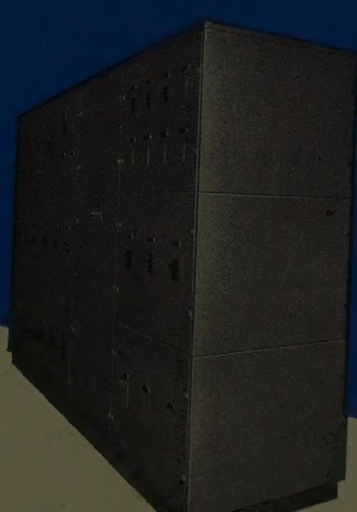
Inherent in the design of the tower is recognition that the researcher needs efficient lighting, flexibility of power supply for his equipment requirements, and uncontaminated air for obtaining true results from his efforts. Power for lighting, motor loads and air conditioning is supplied through a versatile power distribution system planned by Samuel R. Lewis & Associates, Engineers, Chicago. Protecting the system are an I-T-E coordinated outdoor substation, two I-T-E indoor unit substations, and an I-T-E distribution panelboard.

I-T-E Circuit Breaker Company—the center of switchgear progress—is proud of its contribution to the progress of Johnson's Wax.





The I-T-E Company

PHILADELPHIA
PENNSYLVANIA

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three new bulletins: bulletin *212B* describes 1,000- and 2,500-volt d-c Hypass 3-terminal network feed-through capacitors; bulletin *602* gives ratings and sizes of standard Bulphate flat ceramic capacitors; and bulletins *403B* and *402F* contain revised standards for Ceroc 200 and Ceroc T high-temperature magnet wires. All bulletins are available upon request to the company.

Protection for Aluminum. "Amorphous Phosphate Coatings for Protection of Aluminum Alloys and for Paint Adhesion," an article by Alfred Douty and F. P. Spruance, Jr., may be obtained upon request from the American Chemical Paint Company, Ambler, Pa.

Vibrotron. The Institute of Inventive Research, 8500 Culebra Road, San Antonio 6, Tex., has issued a booklet, "Reports on the Vibrotron." The Vibrotron is a new measuring device based on the principle of the vibrating string. Copies of the booklet are available from the company upon written request.

Electronic Equipment. A 1,053-page catalogue which lists the products of the major radio-electronic equipment manufacturers in the United States, complete with prices and discounts, is available to authorized purchasing agents who write on their company letterhead stating their official capacity. Address Department *A-E*, Milo Radio and Electronics Corporation, 200 Greenwich Street, New York 7, N. Y.

Polyphase Induction Motors. The large polyphase induction motor, and its place in the industrial picture, is the subject of a new 28-page booklet (*B-4739*) available from the Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa.

Static Magnetic Memory. Three booklets which describe the potential use, operating characteristics, and some application techniques of the Alden static magnetic memory are available from the Alden Products Company, 117 North Main Street, Brockton 64, Mass.

Capacitors. Ninety different standard ratings of Sprague Cera-mite capacitors, together with complete performance characteristics, are included in Sprague-Herlec engineering bulletin *601B*, available from the Sprague Electric Company, North Adams, Mass.

Stainless Croloy Tubes and Pipe. A 104-page leatherbound handbook, "The Properties and Methods of Working Seamless and Welded Tubes and Pipe of the B&W Stainless Croloys," is offered upon request by the Babcock and Wilcox Tube Company, Beaver Falls, Pa. Intended for engineers, designers and fabricators, it is designed to serve as a guide in choosing the proper material and as a help in planning the conversion of stainless steel tubing into finished products for industry.